MAKE YOUR OWN THUNDERSTORM

SEE INSIDE A BIONIC EYE

# HOW IT WORKS

COULD WE BUILD STAR TREK'S ENTERPRISE?

WHAT THE ROMANS TAUGHT US

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## ALL ABOUT THE INTERNET

HOW COMPUTERS AND CABLES CONNECT TO GIVE YOU ACCESS TO THE WORLD AT THE CLICK OF A BUTTON

> WHAT IS BIOFUEL?

> HOW BLUETOOTH WORKS

> CENTRAL LOCKING EXPLAINED

JAWS OF LIFE: MEET THE FIREFIGHTER'S FRIEND

WHAT ARE SATURN'S RINGS MADE OF?

HOW DIAMONDS ARE MINED AND MADE

WHY OSTRICHES ARE UNABLE TO FLY

FUTURE
ISSUE 161

AIRFIX

# QUICK BUILD

- Stickers Included
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J6036
FORD MUSTANG GT

## Ford Mustang GT
### Build an Iconic Model

The sixth generation Ford Mustang (S550) is the current iteration of the Mustang pony car manufactured by Ford. In departure from prior Mustang models, the sixth generation Mustang includes fully independent rear suspension on all models, as well as an optional 2.3L EcoBoost turbocharged and direct injected four-cylinder engine. The new Mustang was introduced as a 2015 model year vehicle, marking the fiftieth anniversary of the Ford Mustang, which was revealed as a 1965 model year vehicle on April 17, 1964. The sixth generation is also the first Ford Mustang to be marketed and sold globally, and represented the first time that factory right hand drive Mustangs were produced in addition to the left hand drive models.

**This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. Recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.**

**No glue!**
**No paint!**
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# WELCOME

Issue 161

"A network of more than 750,000 miles of cable running under land and sea"

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**All about the internet**
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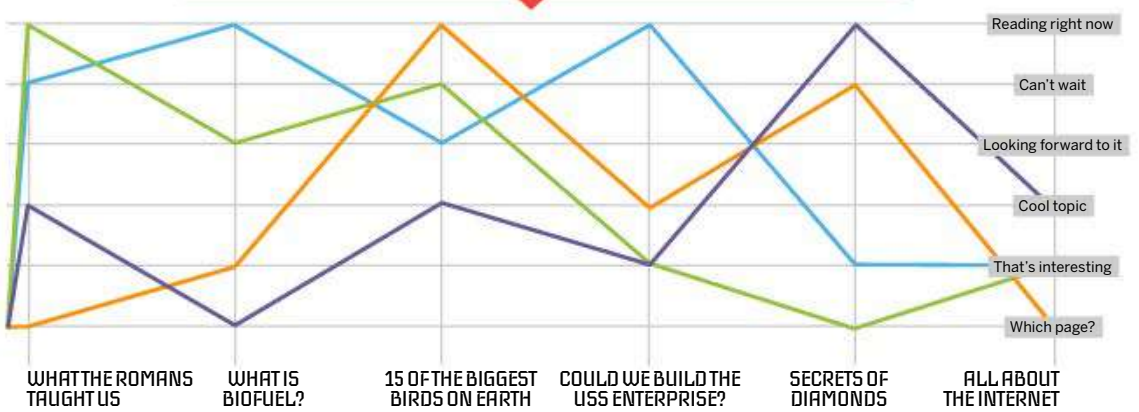
**SUBSCRIBE NOW**
GO TO PAGE 24 FOR GREAT DEALS

Maybe you were born this side of the new millennium, or maybe you're old enough to remember a time when you had to go to the library to get more information on a subject, step outside your house to go shopping or phone a friend to stay in touch. In any case, today the internet is a staple for most of us, every bit as essential a utility to modern living and working as electricity. We take for granted the fact that we can pick up our phones or use a PC to access a cornucopia of data and services, but most of us don't understand how it all works. In this issue, discover how miles of cables, millions of computers and sophisticated software programs come together to connect you to an online world. Enjoy!

**Ben Biggs**
EDITOR

## WHAT WE'RE ANTICIPATING



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STAFF WRITER

AILSA
STAFF WRITER

DUNCAN
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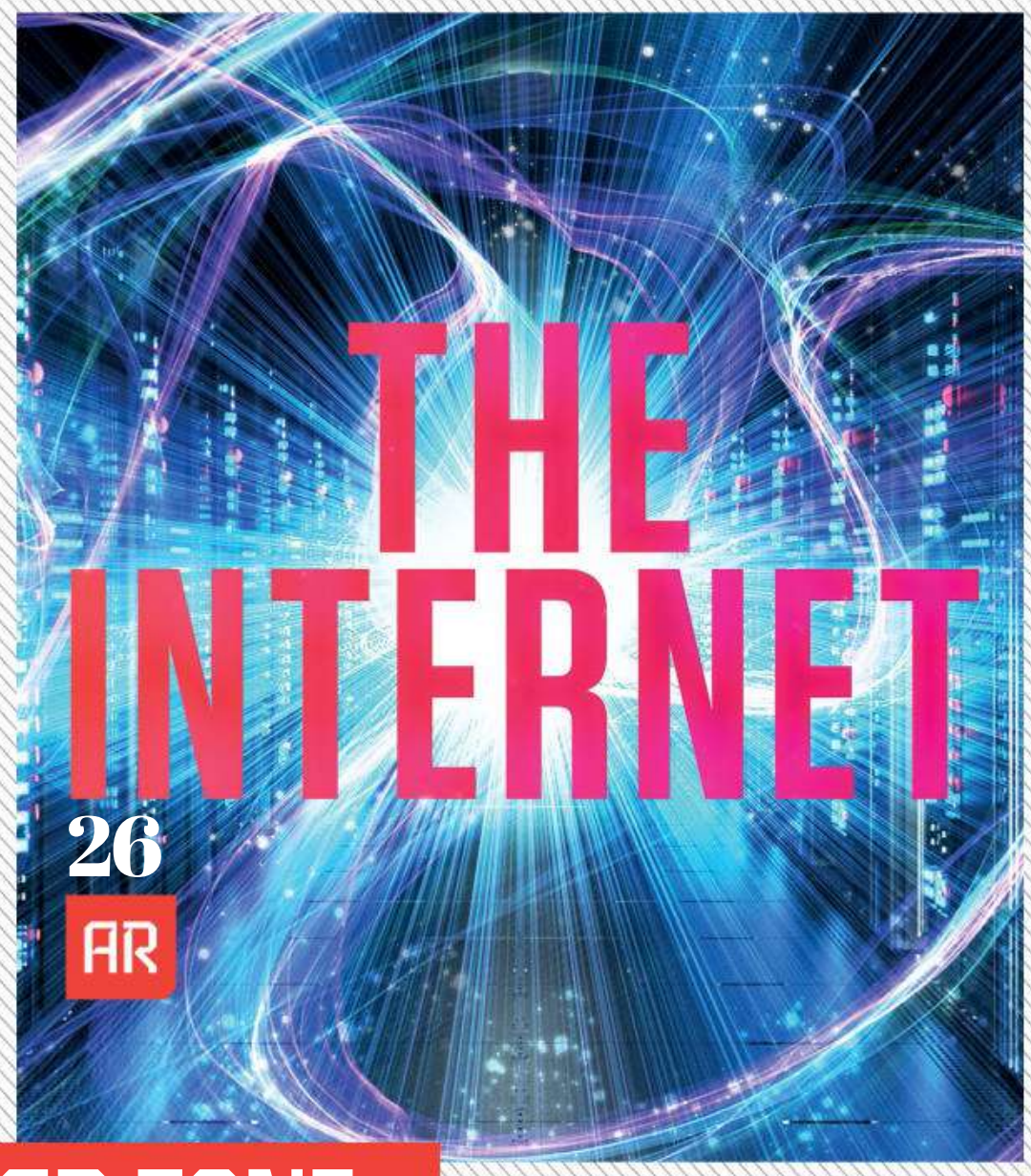
# INSIDE

Issue 161

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## AR ZONE

### Bring the pages to life

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

When you see the AR ZONE logo at the top of a page, use your phone to scan the QR code, which looks like this:

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Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

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## MEET THIS ISSUE'S EXPERTS

**ANDY EXTANCE**
Andy is a science writer. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

**DR ANDREW MAY**
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

**MIKE JENNINGS**
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

**LAURA MEARS**
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

**MARK SMITH**
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

**JO ELPHICK**
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

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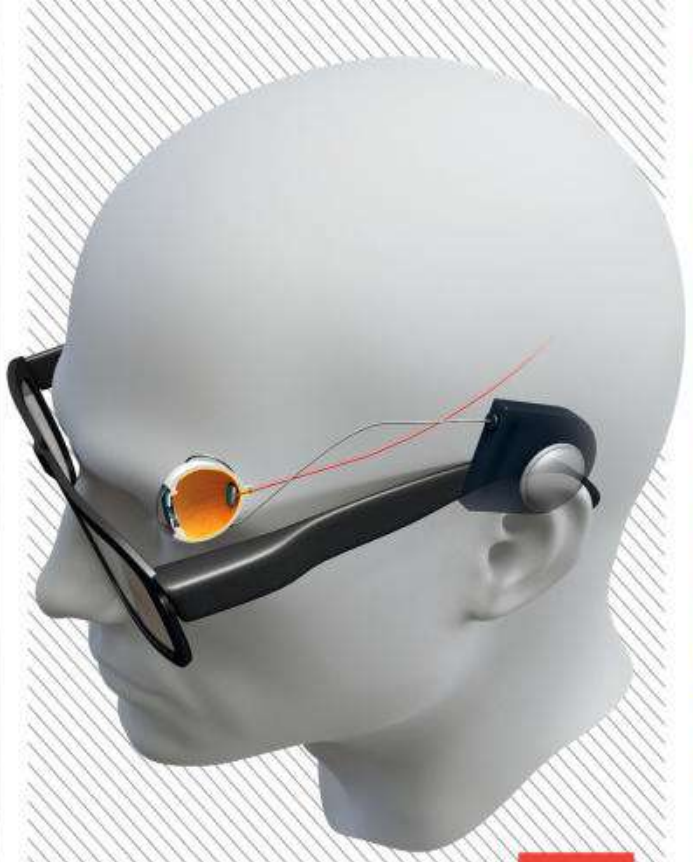

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## WIN A YEAR'S SUBSCRIPTION TO HOW IT WORKS

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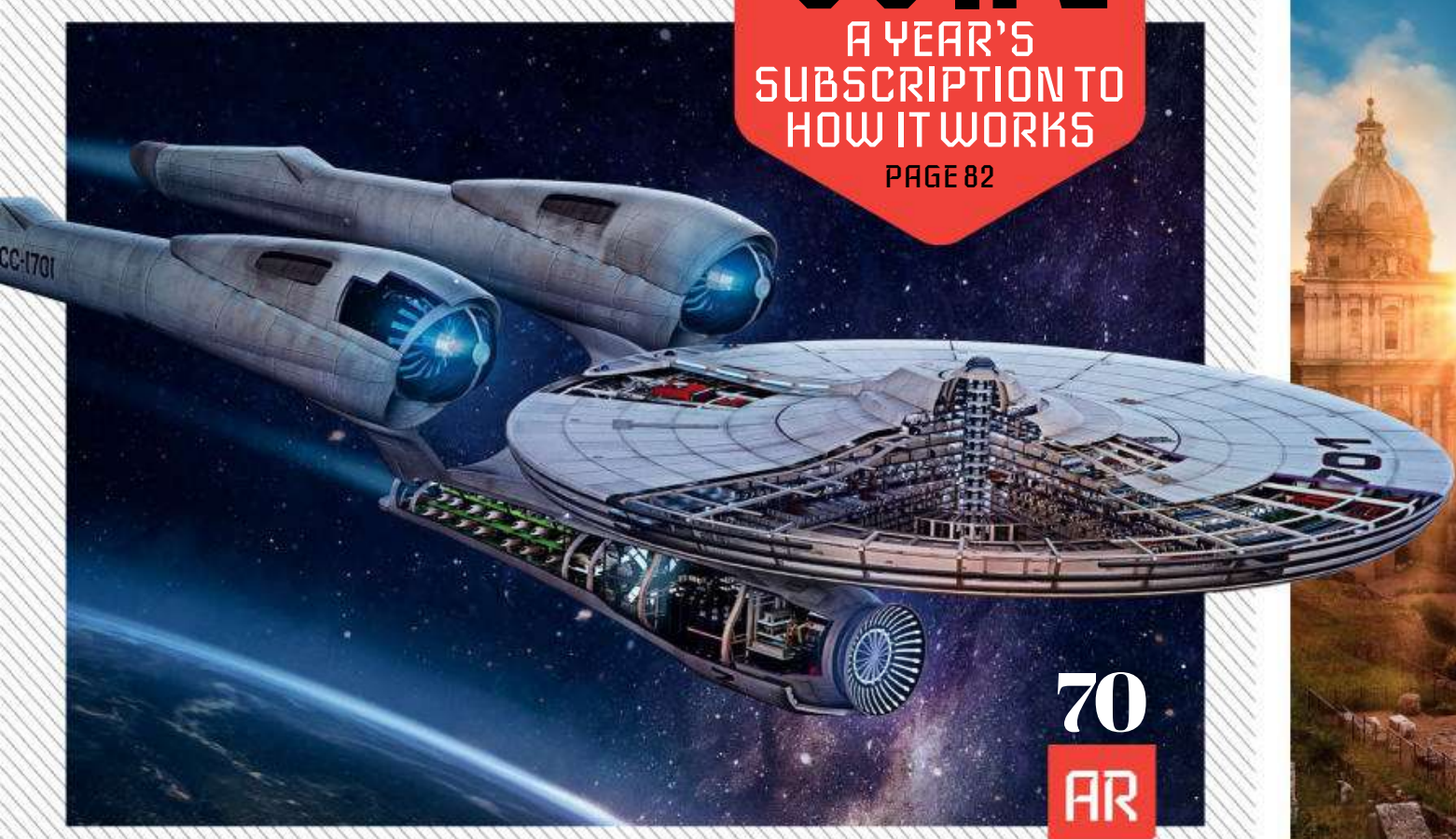

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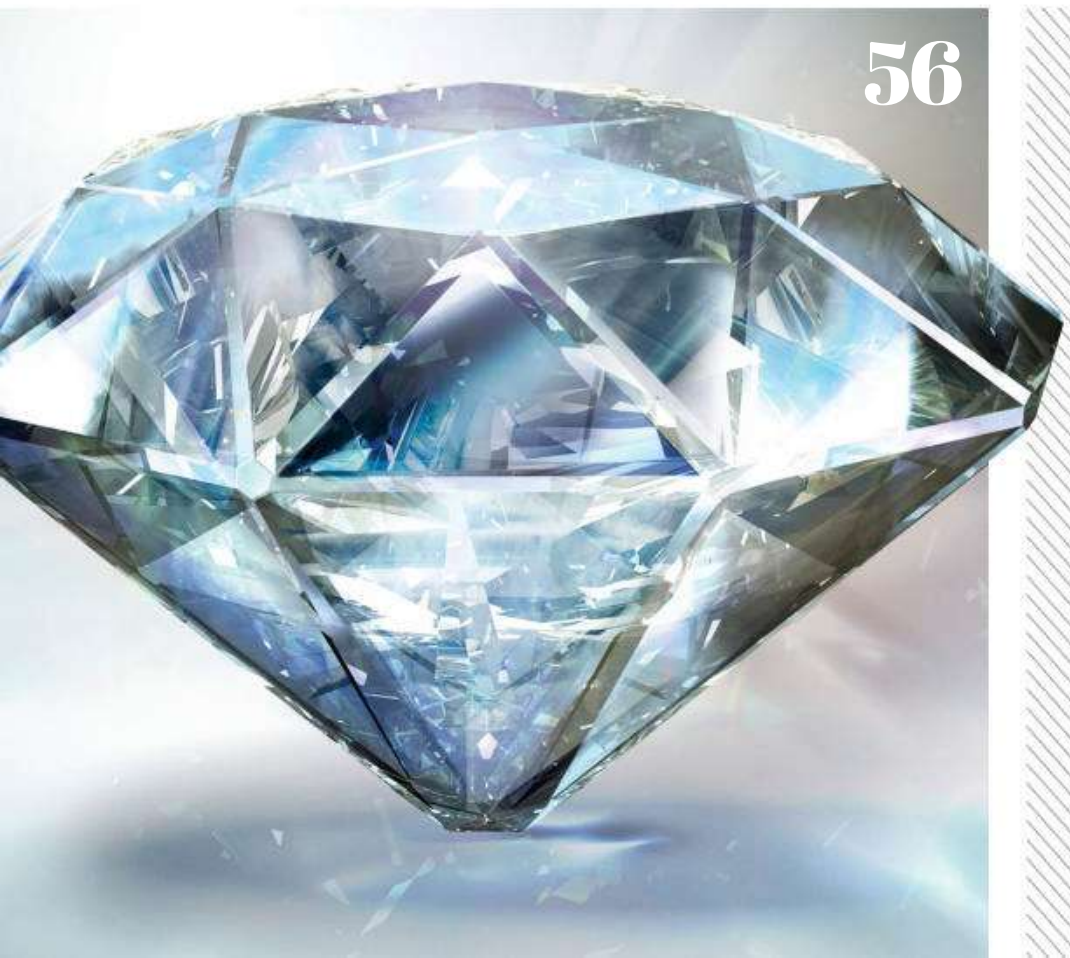

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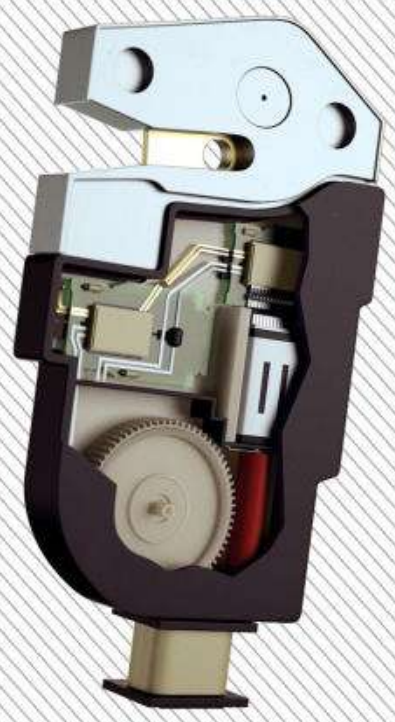

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## Ghostly sea slugs

Meet *Coryphella verrucosa*, the translucent sea slug that's been found as far as 300 metres below the ocean surface. Their bodies are covered in orange protrusions. These are the sites of many of the sea slugs' metabolic functions, such as gas exchange and photosynthesis. At the tip of each strand is a tentacle-like sensory organ called a rhinophore, which acts as the nose.

© Getty

## We have liftoff

It's been one of the most awaited launches in history, but finally the James Webb Space Telescope (JWST) has been successfully launched into space on board an Ariane 5 rocket. Liftoff, pictured here, took place at 13:20 CET from Europe's spaceport in French Guiana on Christmas Day 2021. The JWST will observe deep space using its many onboard instruments, including its huge 6.5-metre-wide, 18-segment gold-coated mirror.

©ESA

# Spreading seeds

This is a scanning electron microscope image of a dandelion seed. The head of a dandelion can hold as many as 400 of these, but they tend to average at around 180. The brown, bulbous portion is known as the achene. The achene dislodges from the head of its parent plant and is carried by an umbrella of white feathery structures called a pappus, acting as a parachute to ride wind currents.

© Getty

# South America's watery border

This is the Paraná River, a 3,030-river waterway that passes through several South American countries and creates, in part, the border between Argentina and Paraguay. The Paraná River is the second-largest river in South America, behind the Amazon. The river breaks into interlocking braided channels after it passes through the 808-metre-long Yacyretá Dam.

© NASA-JSC

It's said that the eyes are the window to the soul, but they may be a window to your health

HEALTH

# Your eyes reveal your true age

WORDS YASEMIN SAPLAKOGLU

By examining tiny vessels inside a person's eyes, doctors might one day be able to predict that person's risk of early death. Though the risks of illness and early death generally increase with chronological age, that risk can vary quite a bit among individuals of the same age. That difference can be explained by a person's 'biological age', which unlike chronological age ticks at an individual rate for each person depending on several health factors.

Previous studies have explored various biomarkers in the body that might be able to determine a person's biological age, including specific genes, cognitive abilities, blood pressure and immune system function. Past research has shown retinae, light-sensitive layers of nerve tissue at the back of the eyes, are a possible indicator of a person's biological age because they can provide clues about disease risk. Researchers turned to a deep-learning technique that could predict a person's risk of death by analysing the biological age of the retinae.

Their deep-learning model, a type of machine learning and artificial intelligence that's modelled to learn similar to a human brain, analysed more than 80,000 images of fundus – the internal back surface of the eye that includes the retina. They obtained the images from nearly 47,000 people between the ages of 40 and 69, stored in the UK Biobank, a biomedical database of more than half a million UK residents. To figure out whether their model was accurate, they first analysed more than 19,000 fundus images taken from more than 11,000 participants who were in relatively good health. The idea was that the retinal biological ages of these people should be fairly similar to their chronological age.

The model was fairly accurate in predicting retinal ages, with an accuracy of within 3.5 years to chronological ages. They then used the model to assess the nearly 36,000 remaining participants' fundus photos, collected across a span of 11 years. They found that 51 per cent of the participants had a 'retinal age gap', the difference between biological and chronological age, of more than three years; 28 per cent had a gap of more than five years and 4.5 per cent had a gap of more than ten years. In other words, these participants had 'older' eyes compared to their chronological age.

Those who had larger age gaps had a 49 per cent to 67 per cent higher risk of death from causes other than cardiovascular disease or cancer. With every one-year increase in the age gap, the risk of death increased by two per cent for any cause and three per cent for causes other than cardiovascular disease and cancer. But they didn't find a link between retinal age gap and death due to cardiovascular disease or cancer. The researchers note that because it was an observational study, they couldn't determine a cause-and-effect relationship.

A view of the city of Anyang in the Chinese province of Henan

HISTORY

## ANCIENT CHINESE WARRIORS WERE BURIED ALIVE

WORDS **TOM METCALFE**

**The 3,000-year-old tombs of a wealthy clan, including the remains of warriors and warhorses that seem to have been sacrificed at their funerals, have been unearthed in an ancient capital city of China. The complex of 24 tombs was discovered at an archaeological site within the city of Anyang in Henan province, less than two miles from the UNESCO World Heritage archaeological site of Yinxu at the city's centre. The ruins there are from the ancient city of Yin, the capital of the Shang dynasty, which ruled between around 1600 BCE to 1046 BCE, the earliest dynasty ever recorded in China.**

**The newfound tomb complex includes several pits that hold war chariots, the remains of horses that drew them and the remains of warriors. Some of the warriors were wearing hats decorated with strings of shells when they died, while the foreheads of some of the horses were decorated with gold veneer and a bronze backing.**

**The practice of the 'ritual suicide' of servants, or 'volunteering' to be buried alive at the funerals of their high-status masters, was common in Shang dynasty China. Archaeologists from Anyang have excavated the site for about two years. So far they have found the foundations of 18 ancient buildings as well as 24 tombs and burial pits for six chariots that also contain the remains of sacrificed men and horses.**

**Did you know?**

**The Titanic iceberg likely split from Ilulissat Icefjord, Greenland**

PLANET EARTH

# Iceberg dumps 132 billion tonnes of water into the ocean

WORDS **BRANDON SPECKTOR**

After the world's largest iceberg snapped off the Antarctic Peninsula in July 2017, it drifted north on a three-year death march, shedding an unfathomable amount of meltwater into the sea. Now, a recent study of the doomed iceberg, named A-68A, reveals just how much water the megaberg actually lost. Using observations from five satellites, the study authors calculated how much the iceberg's area and thickness changed as it drifted north through Antarctica's Weddell Sea and into the relatively warm waters of the Scotia Sea. While the berg headed towards South Georgia Island, iceberg A-68A lost more than 138 billion tonnes of fresh water in just three months, a mass equal to an incomprehensible volume of water that could fill more than 60 million Olympic-sized swimming pools.

"This is a huge amount of meltwater, and the next thing we want to learn is whether it had a positive or negative impact on the ecosystem around South Georgia," said Anne Braakmann-Folgmann, a researcher at the Centre for Polar Observation & Modelling in the UK. "Because A-68A took a common route across the Drake Passage, we hope to learn more about icebergs taking a similar trajectory and how they influence the polar oceans."

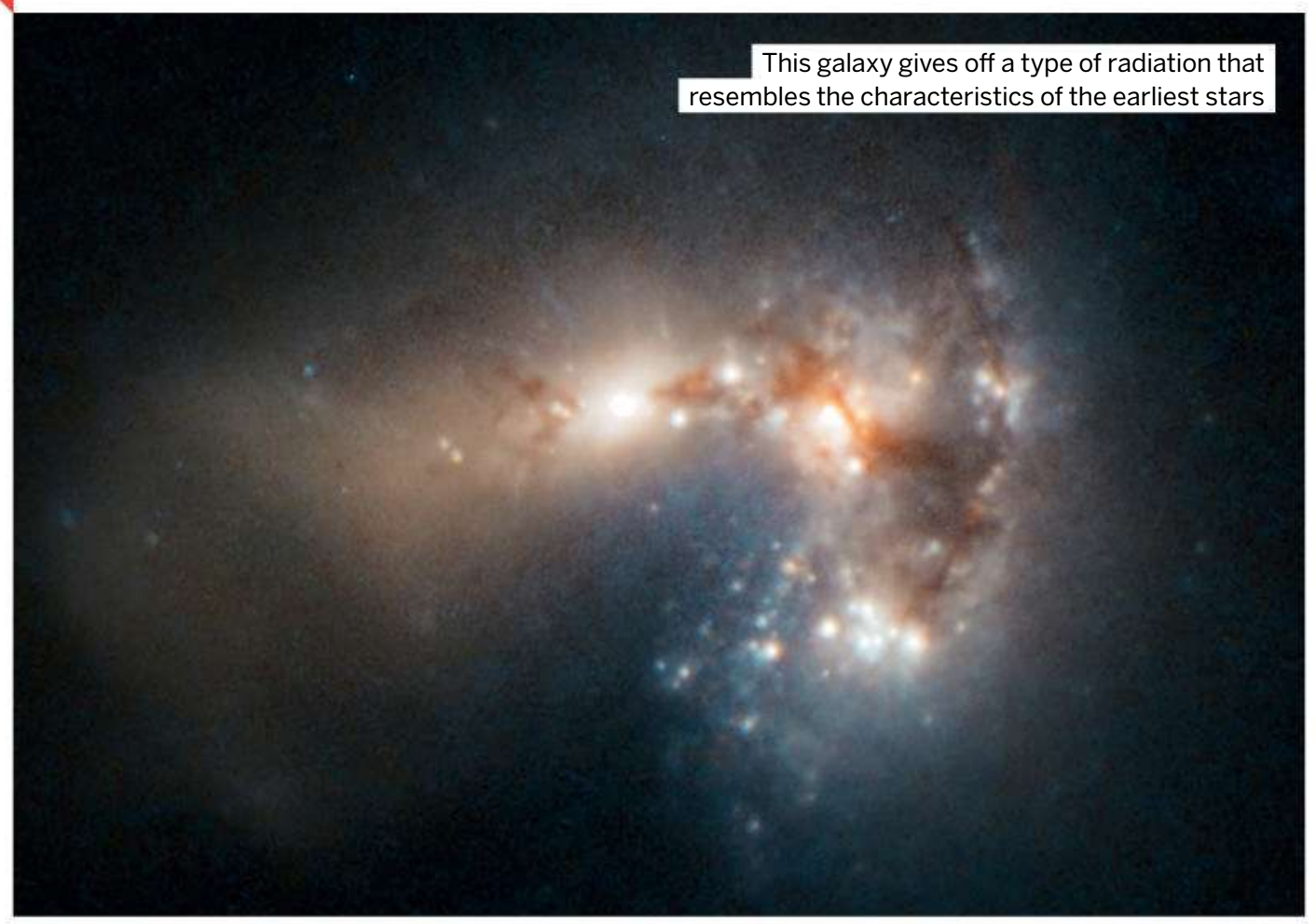
When A-68A broke off the Larsen C ice shelf in northern Antarctica in July 2017, it measured about 2,300 square miles in area. The berg ranked as the sixth-largest iceberg ever observed on Earth and the single largest iceberg floating through the ocean during its 3.5-year life span. A-68A bumped through the chilly Weddell Sea for about two years, moving north at a glacial pace. During this time, the iceberg barely melted and lost little volume.

Only when A-68A drifted north into the Scotia Sea did the real mass loss begin. Once there, the iceberg's melt rate increased by nearly eightfold as the comparatively warm waters lapped away at the iceberg's base and edges. For three months between November 2020 and January 2021, the iceberg reached its peak melt rate, losing more than 136 billion tonnes of ice in that period.

By April 2021, iceberg A-68A had completely melted away. Even with the iceberg having vanished into the sea, its impacts on sea life may not be over. A-68A dumped fresh water into the salty sea around South Georgia Island, along with nutrients that could boost biological production, such as plankton populations. This boost could have widespread impacts on local food chains, though whether that will be a positive or negative in the long term is unknown.

The huge iceberg calved from the Antarctic Peninsula's Larsen C ice shelf on 12 July 2017

© Getty / Alamy / ESA



This galaxy gives off a type of radiation that resembles the characteristics of the earliest stars

SPACE & PHYSICS

# Black holes could explain the universe's origins

WORDS **DORIS ELIN SALAZAR**

Nearby galaxies and their black holes could hold the answers to the existential questions that remain unanswered about the beginning of the universe. A black hole within a nearby galaxy called Tol 0440-381 shines about a million times brighter than the Sun, researchers from the University of Iowa recently found. This object suggests that powerful black holes could have played a major role in cosmic evolution.

Hundreds of thousands of years after the Big Bang, the universe was transparent for some time and had no stars. These dark ages ended about 400,000 years after the Big Bang, when the first stars began to form and light flooded the young cosmos.

These earliest stars were behemoths, about 30 to 300 times as massive as our Sun and millions of times as bright. These powerful stellar furnaces burned for only a few million years before exploding as supernovae.

While their lives were short and extreme, these earliest stars had a tremendous impact on our modern universe. The high-energy explosions released tremendous energy into space – energy powerful enough to split hydrogen atoms into electrons and protons, establishing a new period in the universe's history dubbed the Epoch of Reionisation, which arose with the universe's first stars and galaxies and lasted until about a billion years after the Big Bang.

The powerful light these stars emitted and their frequent transformations into black holes after going supernova likely played a huge role in shaping the future galaxies that would soon populate the universe. The details of exactly how this all happened are still unclear, however.

The James Webb Space Telescope arrived at its final home in January 2022, and scientists aim to use its next-generation instruments to help answer such questions about the universe's adolescence. In the meantime, the researchers are working on this question by studying nearby galaxies with instruments already in full working order. Using data collected by NASA's Chandra X-Ray Observatory in February 2021, the team identified the powerful black hole within Tol 0440-381 and found similarities to the early stars that powered the Epoch of Reionisation.

"The implication is that outflows from black holes may be important to enable escape of the ultraviolet radiation from galaxies that reionised the intergalactic medium," said Philip Kaaret, professor and chair in the department of physics and astronomy at the University of Iowa. "We can't yet see the sources that actually powered the universe's reionisation because they are too far away."

ANIMALS

# REIGN OF NEW MONKEY QUEEN IS IN JEOPARDY

WORDS **BRANDON SPECKTOR**

**In southern Japan, a young female macaque upended societal norms by seizing control of her 677-member troop through a violent coup. Now her hard-won empire could be coming to an end. Yakei is a nine-year-old macaque living in a Japanese reserve, the Takasakiyama Natural Zoological Garden, where she has spent the last year reigning as the first female troop leader in the park's 70-year history. After assuming the role of top female, Yakei tackled the troop's four highest ranking males, finally assuming the troop's coveted alpha position after beating up a 31-year-old male who had ruled the troop for five years.**

**Hostile takeovers by aggressive females are exceptionally rare in Japanese macaque society, with only a handful of recorded cases preceding Yakei's coup. Macaques live in strictly hierarchical societies. A male's rank is usually determined by how much time he has spent in a troop, while female macaques inherit the rank below their mother's. Sometimes macaques can violently seize higher ranks. These contests are almost exclusively between males, which is why Yakei's rise to power was shocking.**

**After nearly a year in the top spot, Yakei's position may be in jeopardy during the chaos that is mating season. An 18-year-old male named Luffy has been making unwanted courtship advances on Yakei since this year's breeding season began. Luffy could be in the process of dethroning Yakei, or this could just be a simple matter of courtship.**

A Japanese macaque bathing in a hot spring in winter

ANIMALS

# Antarctic penguin colony concerns scientists

WORDS **LAURA GEGGEL**

Scientists have discovered a previously unknown colony of gentoo penguins in one of the southernmost spots these waddling birds have ever been spotted. The discovery is a cause for concern that climate change is expanding the range of this temperate, non-ice-loving species of penguin.

And this isn't the only concerning find. In addition to this gentoo penguin (*Pygoscelis papua*) colony, with 75 nests on Anderson Island, gentoo penguins have also been sighted on an unexplored archipelago off the Antarctic Peninsula's northern tip. Both are among the first records of the species breeding so far south on the eastern side of the Antarctic Peninsula. Previously, these areas were too icy for gentoo penguins, which prefer temperate climes where they can raise their chicks. These penguins, the third-largest living penguin species, are native to warmer sub-Antarctic islands, such as the Falkland Islands off Argentina. They usually live in ice-free areas, such as flat, rocky beaches and low-lying cliffs where large colonies can gather.

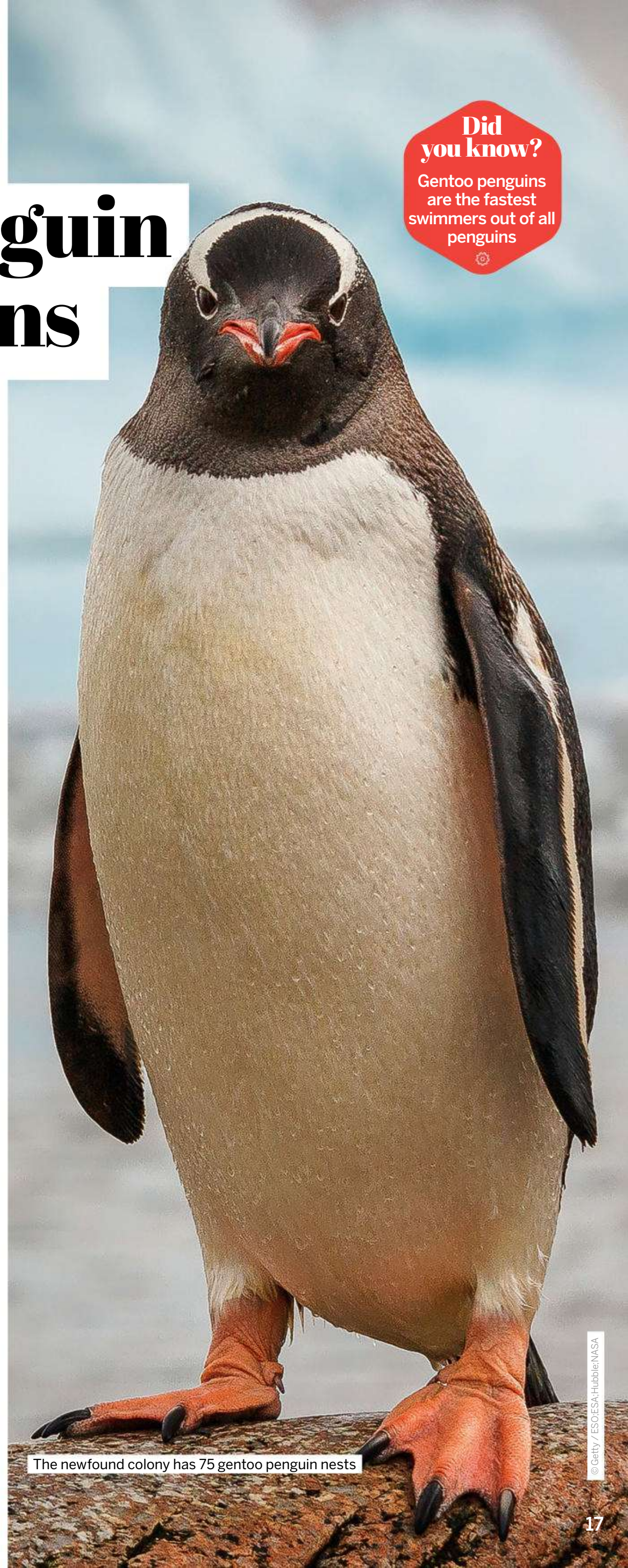
During a recent expedition, Greenpeace invited independent scientists aboard its icebreaker vessel MV Arctic Sunrise to sail through the Weddell Sea and help count penguins on the southern continent. "Mapping out these remote archipelagos will give us a better understanding of how the region's penguins are responding to rapid climate change," said Heather J. Lynch, a professor of ecology and evolution at Stony Brook University in New York. "As expected, we're finding gentoo penguins nearly everywhere we look – more evidence that climate change is drastically changing the mix of species here on the Antarctic Peninsula."

Until now, just one solitary gentoo penguin nest had been spotted this far south. Gentoo penguins don't migrate, so conditions have to be ideal for them to stay in one location year-round. "They're very opportunistic, so any chance they get, they're going to colonise rock as the glaciers retreat," Lynch said. "They're the thing that we tend to use to see how far climate change has gone in terms of turning the Antarctic Peninsula into a more sub-Antarctic or more temperate climate."

Many penguin populations are in flux due to the rapidly changing climate and increased industrial fishing. For instance, ice loss in Antarctica has increased sixfold over the last 30 years. One of Antarctica's largest glaciers, Thwaites Glacier – also known as the 'Doomsday Glacier' – could collapse in just a few years, possibly increasing sea levels worldwide by more than 65 centimetres. To help native animals struggling in a warming Antarctic, scientists and conservationists are pushing for three new marine protected areas around the southern continent, including in East Antarctica, the Antarctic Peninsula and the Weddell Sea, which would span 1.5 million square miles. "Governments need to agree [to] a new Global Ocean Treaty to deliver protection for at least 30 per cent of the world's oceans by 2030 – and they must get to work by protecting the Antarctic's waters," said Louisa Casson of Greenpeace's Protect the Oceans campaign.

**Did you know?**

Gentoo penguins are the fastest swimmers out of all penguins



The newfound colony has 75 gentoo penguin nests

© Getty / ESO:ESA:Hubble:NASA

PLANET EARTH

## ‘GATES OF HELL’ MAY FINALLY BE CLOSED

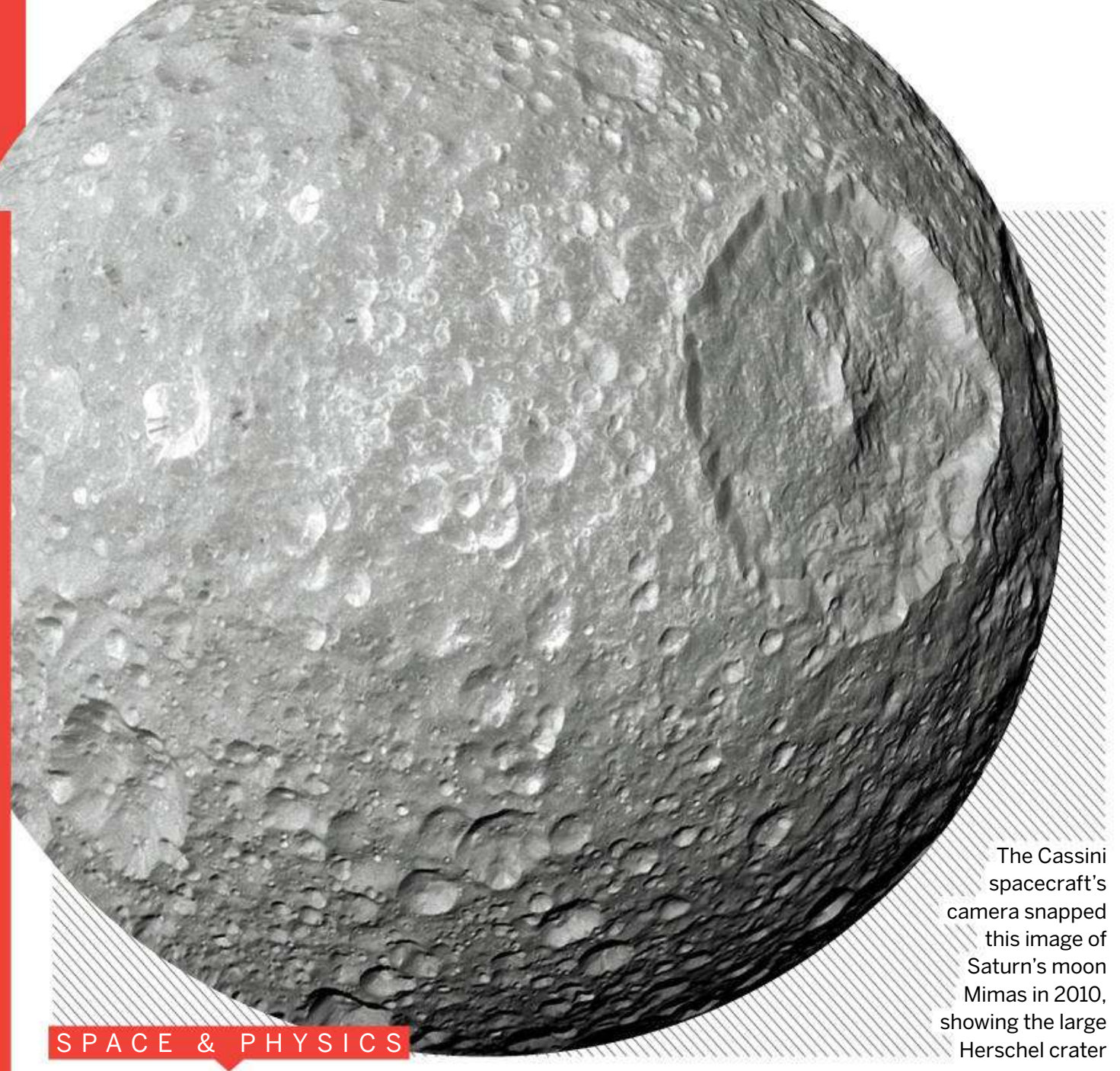
WORDS **BRANDON SPECKTOR**

**The leader of Turkmenistan would like to finally close the ‘Gates of Hell’ that have burned continuously in the nation’s Karakum Desert for five decades. On an appearance on Turkmenistan’s state TV channel, President Gurbanguly Berdymukhamedov urged officials to “find a solution to extinguish the fire,” citing concerns for the health of people living near the flaming crater, as well as lost business opportunities.**

**The Gates of Hell, also known by the far-less-apocalyptic name of the Darvaza gas crater, are a large hole in the desert measuring roughly 70 metres wide and at least 20 metres deep. Excavation of the hole began in 1971 during a Soviet drilling operation to extract gas – Turkmenistan being an ex-Soviet nation. Disaster struck when the ground beneath the drill rig collapsed and it plunged into a natural gas cavern. As noxious methane gas leaked into the air, geologists decided to set the crater on fire, estimating that the gas within would only burn for a few weeks.**

**But 50 years later, the Gates of Hell still blaze, and they’ve even become one of Turkmenistan’s top tourist destinations. Turkmenistan sits atop the fourth-largest known reserve of natural gas in the world, and the country’s economy is largely dependent on gas exports. President Berdymukhamedov previously ordered experts to quell the Gates of Hell in 2010, though those efforts were unsuccessful.**

The ‘Gates of Hell’ have been ablaze in the desert of Turkmenistan since 1971



The Cassini spacecraft’s camera snapped this image of Saturn’s moon Mimas in 2010, showing the large Herschel crater

SPACE & PHYSICS

# ‘Death Star’ moon’s secret underground ocean

WORDS **BEN TURNER**

Scientists have found compelling evidence that Saturn’s ‘Death Star’ moon is hiding an ocean just beneath its surface, furthering the search for possible life in our Solar System. Researchers say Mimas, Saturn’s smallest, innermost moon, whose resemblance to *Star Wars*’ infamous battle station inspired its nickname, revealed the first clue that it could be a ‘stealth ocean world’ after NASA’s Cassini probe spotted a strange wobble in the moon’s rotation.

Recent research suggests that the wobble could be the result of the sloshing of a liquid ocean trapped just beneath the icy surface of the 246-mile-diameter moon. If this is the case, researchers say that Mimas is an entirely new type of world. The discovery of the tiny moon’s secret ocean could mean that water, and the possible life it can sustain, could be far more abundant in our Solar System than first thought. “If Mimas has an ocean, it represents a new class of small ‘stealth’ ocean worlds with surfaces that do not betray the ocean’s existence,” said Alyssa Rhoden, a geophysicist at the Southwest Research Institute in San Antonio, Texas.

Interior water ocean worlds, such as Saturn’s Enceladus or Jupiter’s Europa, are not new to scientists, but inner tidal processes tend to fracture their surfaces and they show other signs of geological activity. Mimas, on the other hand, looked at first glance like it was “just a frozen block of ice,” Rhoden said. “Turns out Mimas’ surface was tricking us, and our new understanding has greatly expanded the definition of a potentially habitable world in our Solar System and beyond.”

To investigate the possibility of a hidden ocean under Mimas’ frozen surface, the researchers built a model to see if its gravitational interactions with Saturn could produce the tidal forces necessary to heat the moon’s interior, keeping the water below its 15 to 20-mile-thick ice shell warm enough to remain liquid. “Most of the time when we create models, we have to fine-tune them to produce what we observe,” Rhoden said. “This time evidence for an internal ocean just popped out of the most realistic ice-shell stability scenarios and observed librations [planetary wobbles].” This makes Mimas a compelling target for investigation. By studying the moon’s ability to support an ocean, scientists could glean a better understanding of other potential hidden ocean moons tucked farther out in our Solar System, such as the moons of Uranus.

**Did you know?**

**Herschel crater measures 86 miles in diameter**

SPACE & PHYSICS

# Astronomers watch a star explode in real time

WORDS BRANDON SPECKTOR

Astronomers watched a giant star blow up in a fiery supernova for the first time ever, and the spectacle was even more explosive than researchers anticipated. Scientists began watching the doomed star, a red supergiant now designated SN 2020tlf, located about 120 million light years from Earth, more than 100 days before its final violent collapse.

During that lead-up, the researchers saw the star erupt with bright flashes of light as great globs of gas exploded out of the star's surface. These pyrotechnics came as a big surprise, as previous observations of red supergiants about to blow showed no traces of violent emissions. "This is a breakthrough in our understanding of what massive stars do moments before they die," said Wynn Jacobson-Galán of the University of California, Berkeley. "For the first time, we watched a red supergiant explode."

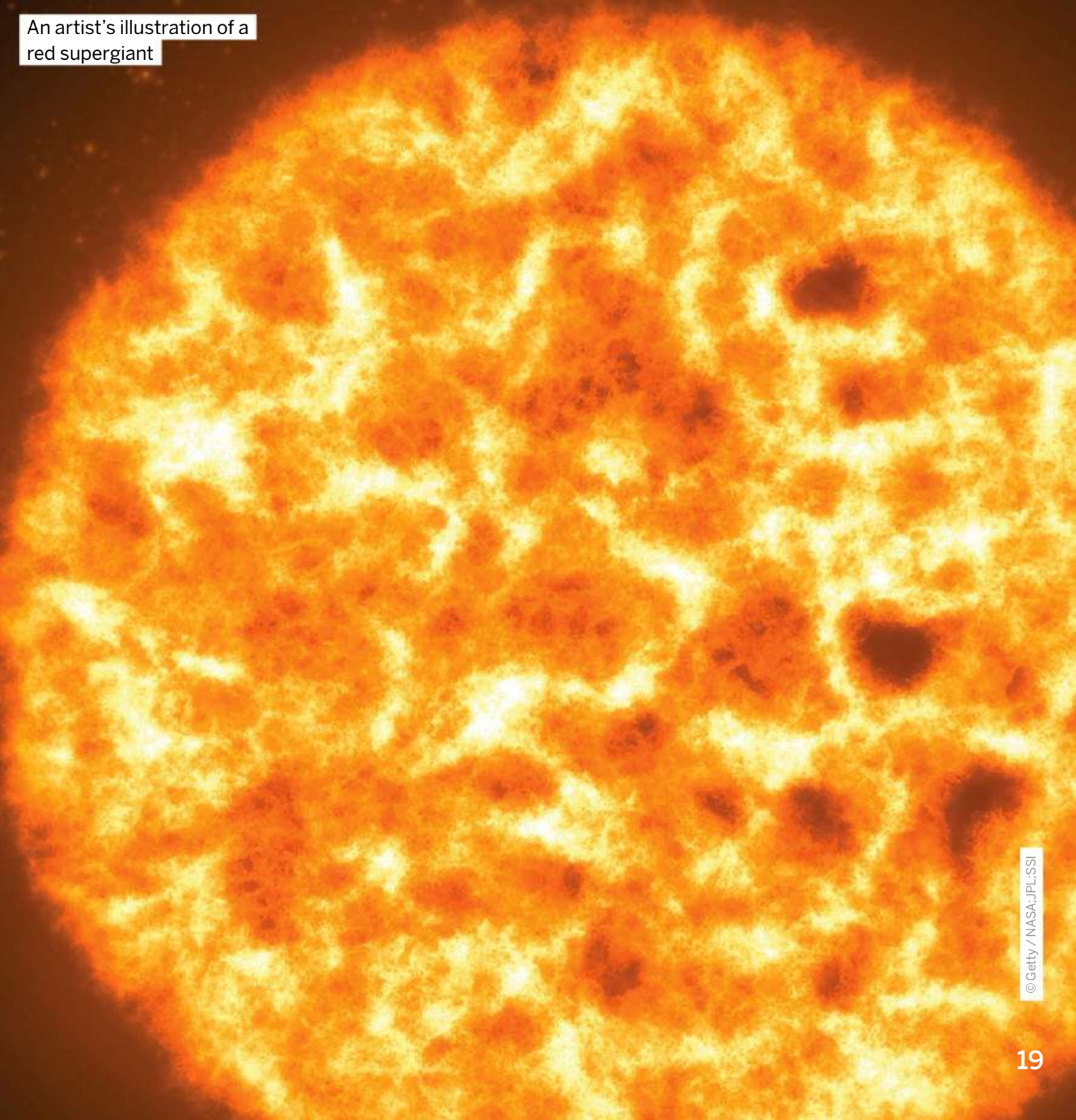
Red supergiants are the largest stars in the universe in terms of volume, measuring hundreds or sometimes more than a thousand times the radius of the Sun – though they're not the brightest nor the most massive stars out there. Like our Sun, these massive stars generate energy through the nuclear fusion of elements in their cores. But because they are so big, red supergiants can forge much heavier elements than the hydrogen and helium that our Sun burns.

As supergiants burn ever more massive elements, their cores become hotter and more pressurised. Ultimately, by the time they start fusing iron and nickel, these stars run out of energy, their cores collapse and they eject their gassy outer atmospheres into space in a violent Type II supernova explosion.

Scientists have observed red supergiants before they go supernova, and they have studied the aftermath of these cosmic explosions, but they've never seen the whole process play out in real time until now.

Researchers began observing SN 2020tlf in the summer of 2020, when the star flickered with bright flashes of radiation that the team later interpreted as gas exploding off the star's surface. Using two telescopes in Hawaii – the University of Hawaii Institute for Astronomy Pan-STARRS1 telescope and the W. M. Keck Observatory on Mauna Kea – the researchers monitored the cranky star for 130 days. Finally, at the end of that period, the star went boom.

The team saw evidence of a dense cloud of gas surrounding the star at the time of its explosion, likely the same gas that the star ejected during the prior months. This suggests that the star started experiencing violent explosions well before its core collapsed in the autumn of 2020. "We've never confirmed such violent activity in a dying red supergiant star where we see it produce such a luminous emission, then collapse and combust, until now," said Raffaella Margutti, an astrophysicist also at UC Berkeley. These observations suggest that red supergiants undergo significant changes in their internal structures at the end of their life, resulting in chaotic explosions of gas in their final months before collapsing.

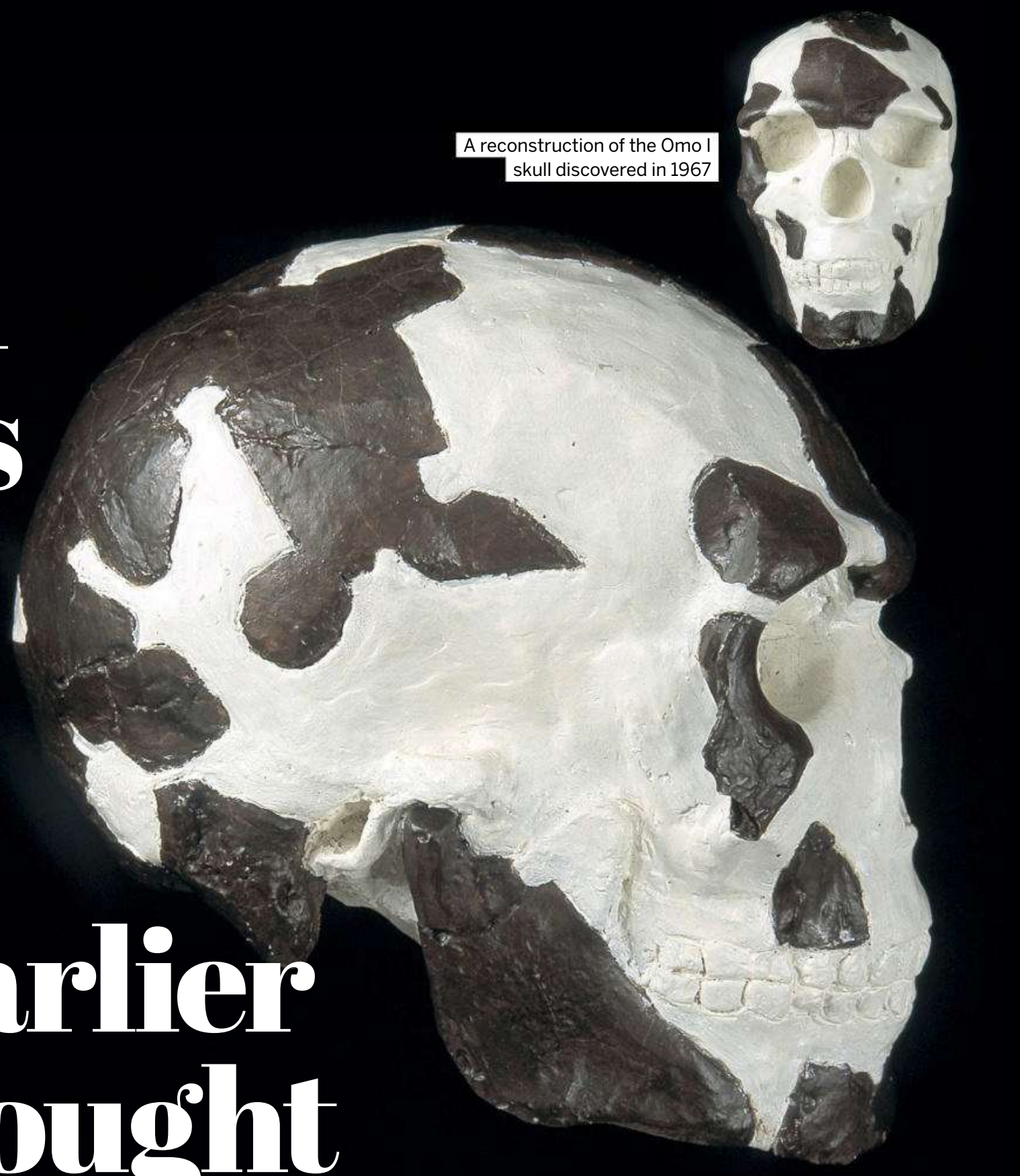


An artist's illustration of a red supergiant

© Getty / NASA; JPL; SSI

HISTORY

# Modern humans lived in Africa 38,000 years earlier than thought



A reconstruction of the Omo I skull discovered in 1967

WORDS BEN TURNER

Modern humans emerged in eastern Africa at least 38,000 years earlier than scientists previously believed. That conclusion was drawn from traces of a colossal volcanic eruption used to date the earliest undisputed *Homo sapiens* fossils. The remains, dubbed Omo I, were discovered at the Omo Kibish site near Ethiopia's Omo River in the 1960s. Previous estimates dated the human fossils to around 195,000 years old. But recent research tells a different story – that the remains are older than a colossal volcanic eruption that rocked the region roughly 233,000 years ago.

The new estimate places the fossils even more firmly among the oldest *Homo sapiens* remains ever discovered in Africa, second only to 300,000-year-old specimens found at the Jebel Irhoud site in Morocco in 2017. However, the Jebel Irhoud skulls vary enough in their physical characteristics from those of modern humans for some scientists to contest their classification as *Homo sapiens*. This means that the new discovery marks the oldest uncontested dating of modern humans in Africa. "Unlike other Middle Pleistocene fossils, which are thought to belong to the early stages of the *Homo sapiens* lineage, Omo I possesses unequivocal modern human characteristics, such as a tall and globular cranial vault and a chin," said Aurélien Mounier, a palaeoanthropologist at the Musée de l'Homme in Paris, referring to the globular cranial vault as the space where the brain sits inside the skull. "The new date estimate makes it the oldest unchallenged *Homo sapiens* in Africa."

It's probably no coincidence that some of humanity's earliest ancestors lived in a geologically active rift valley. The tectonic activity created lakes that collected rainwater, not only providing fresh water but also attracting animals to hunt, and the 4,350-mile-long Great Rift Valley, of which the East African Rift System is just a small part, served as an enormous migration corridor for humans and animals that ran from Lebanon in the north all the way to Mozambique in the south.

Despite having found the minimum age of the Omo I samples, the researchers still need to find a maximum age for both these fossils and the wider emergence of *Homo sapiens* in eastern Africa. They plan to do this by linking more buried ash to more eruptions from volcanoes around the region, giving them a firmer geological timeline for the sedimentary layers around which fossils in the region are deposited. "Our forensic approach provides a new minimum age for *Homo sapiens* in eastern Africa, but the challenge still remains to provide a cap – a maximum age – for their emergence, which is widely believed to have taken place in this region," said Christine Lane, a geochronologist at Cambridge University. "It's possible that new finds and new studies may extend the age of our species even further back in time."

A double-collared sunbird is a tiny, colourful bird that resembles a hummingbird

ANIMALS

# Sunbird songs are a million years old

WORDS YASEMIN SAPLAKOGLU

A million years ago, the soundtrack of the 'sky island' mountains of East Africa may have been similar to what it is today. That's because a group of tiny, colourful birds have been singing the exact same tunes for more than 500,000 years, maybe as long as a million years. Sunbirds in the family Nectariniidae are colourful, tiny, nectar-feeding birds that resemble hummingbirds and are common throughout Africa and Asia. They are "little jewels that appear before you," said Rauri Bowie, a professor of integrative biology at the University of California, Berkeley, and a curator in the school's Museum of Vertebrate Zoology.

The eastern double-collared sunbird (*Cinnyris mediocris*), also known as the sky island sunbird, lives at the peaks of tall mountains in East Africa from Mozambique to Kenya. These skyscraping peaks have isolated different populations, or lineages, of this species from one another for tens of thousands to a million years. But despite not interacting at all, many populations of sky island sunbirds are indistinguishable from each other.

Researchers wondered if the birds' songs had also remained unchanged through the eons. To answer this question, they visited 15 separate sky islands in East Africa between 2007 and 2011, recording the songs from 123 individual birds from six different sunbird lineages. It turns out that some of these isolated populations still sing the same songs. That suggests that these songs haven't evolved much in the thousands of years that these lineages have been separated.

The researchers' findings were surprising, as biologists typically expect bird songs to evolve and change through time in different populations. The idea that bird songs rapidly evolve likely came from studying birds in the Northern Hemisphere, where environmental conditions have changed a number of times over tens of thousands of years. Northern Hemisphere birds are thought to have evolved new colours, songs and behaviours to better adapt to new environments, such as the presence or absence of glaciers.

But the mountains of East Africa have seen very little geological change, suggesting that the sunbirds had no reason to evolve different plumage or songs. The researchers concluded that birds and their songs can stay unchanged for millions of years, until environmental shifts cause them to evolve quickly or in pulses. Now the scientists are continuing their research in East Africa to figure out why some birds evolve newer songs and others don't.

**Did you know?**

**Sunbirds have curved beaks to help them drink nectar**

HEALTH

## RABIES DEATHS IN THE US SPARK WARNING

WORDS YASEMIN SAPLAKOGLU

**Five people died of rabies in the US in 2021, three of them within a five-week period. This follows two years of zero cases and is the highest number reported per year in over a decade. The cases were all exposed to bats between 28 September and 3 November 2021, and none of them sought out post-exposure prophylaxis (PEP), a series of vaccines vital for preventing rabies after exposure.**

**Rabies deaths in the US are rare, with typically one to three cases reported annually. The recent uptick prompted the Centers for Disease Control and Prevention to raise awareness about the risks of the fatal disease. As the number of rabid bats reported to the National Rabies Surveillance System has been about the same since 2007, the uptick might not be attributable to an increase in rabid bats, but rather a lack of awareness about the risks of rabies and the necessity of receiving PEP.**

**Rabies is caused by a virus that infects the central nervous system, and typically spreads through a bite or scratch from a rabid animal. PEP is nearly 100 per cent effective at preventing rabies before symptoms appear; once they do, rabies is almost always fatal. About 60,000 people receive the shots in the US each year. One of the three cases didn't receive PEP because of a fear of vaccines and the other two patients didn't realise the risk because they either didn't notice a bite or scratch or they didn't realise bats could carry rabies.**

One of the cases involved exposure to a big brown bat (*Eptesicus fuscus*)

© Alamy / Getty

# WISH LIST

## The latest VR HEADSETS

## OCULUS QUEST 2

**WWW.OCULUS.COM FROM £299 / $299**

Wirefree and self-contained, the Oculus Quest 2 is the perfect introduction to the delights of virtual reality. Relatively affordable, this wireless headset has everything you need to get into VR gaming right out of the box. It's powerful enough to run some of the most enticing VR experiences without breaking the bank, and taps into Oculus' ever-growing library of exclusive virtual-reality titles.

Its screen isn't the sharpest, but its wireless nature makes it one of the simplest to use and most comfortable to wear. And for those really invested in the virtual-reality scene, it will work with titles originally designed exclusively for PC VR players. This is thanks to the Oculus Quest 2's flexible support for additional wired gameplay through a PC and wireless PC streaming connectivity for those with Wi-Fi connections powerful enough to support them.

## VALVE INDEX

**WWW.STEAMPOWERED.COM £459 / $499**

If you're after the most luxurious of virtual-reality experiences, you're going to want to invest in a Valve Index headset. It's one of the pricier devices on the market, not just because of its high specifications, which include a super-sharp screen and additional tracking stations that need to be dotted around the room, but also because there's the expectation that you'll be hooking this headset up to a relatively high-spec PC. But unfortunately there's no wireless option with the Valve Index kit.

What you get instead is arguably the most immersive VR experience to date, thanks to the Valve Index's wider field of view, high-resolution display and 'knuckle' style controllers, which allow you to use each of your fingers and thumbs individually in a VR environment.

## VIVE PRO 2

**WWW.VIVE.COM £719 / $799**

If you're after sheer fidelity from your PC VR gaming experience, you'll struggle to find a better headset than the HTC Vive Pro 2. With an incredible 5K resolution, it's about as sharp as VR headsets get before entering truly niche enthusiast territory. With a fast refresh rate and wide field of view, you'll really be able to see every detail from your time in VR, to the point where you begin to approach photo-real quality in some high-end apps.

Clarity like this comes at a high price, and we're not just talking about the expense of the HTC Vive Pro 2 kit itself. To be able to power this headset at any sort of stable frame rate, you're going to need a very high-specification PC and graphics card, which may make the whole endeavour prohibitively expensive.

# VIVE COSMOS ELITE

**WWW.VIVE.COM PRICE £549 / $549**

A bit older than the HTC Vive Pro 2, think of the HTC Cosmos Elite as its cheaper, less flashy sibling. Though it doesn't quite have the showstopping specs of the newer Vive Pro 2 model, it still has a lot going for it. Its base stations track movement well, its field of view is relatively wide and its library of games – available through both the Steam VR marketplace and HTC Viveport subscription service – is deep and entertaining.

However, the failings of the Vive Pro 2 are apparent here also – it's the same unwieldy controllers, and you're still going to need to find places to pop its motion-tracking base stations around a room. All things considered, it's still a solid VR choice, especially if its advancing age means you can pick it up at a bargain price.

# HP REVERB G2

**WWW.HP.COM £526.80 / $599**

On the one hand, the HP Reverb G2's high-resolution screens make it strong competition for the Valve Index and HTC Vive Pro 2, but on the other hand its lowly refresh rate means it can't match the natural-feeling smoothness of either of those devices.

Then there's its price. It's much more expensive than the Oculus Quest 2 and PSVR. It doesn't come with controllers in the box, and its wired nature means you're still going to need a rather powerful PC to pair it with. And yet it has a physical IPD slider, letting its lenses more accurately match the distance between your pupils, whereas the Oculus Quest 2 does not.

If you really must have a high-resolution display in your PC VR headset, it's a good option.

# PLAYSTATION VR

**WWW.PLAYSTATION.COM £259.99 / $299.99**

Considering the relatively low-powered PS4 console it's tied to, the wired PlayStation VR headset still offers a damn good time for gamers. Leaning on its first-party development studios and publishing pals, Sony amassed a great library of exclusive titles to play. However, the PlayStation VR gear is now starting to look a little long in the tooth. Though regularly bundled with games well below RRP, its screen resolution is low, its controllers – which are based on an old PS3 motion controller design – are behind the pack, and its cable-laden breakout box is a faff to set up. And while its hardware and software are compatible with the new PS5 console, a PSVR 2 has already been confirmed to be in the works at Sony HQ. If you've not already bought into the idea of VR on your PlayStation, it may be worth holding out for the sequel at this point.

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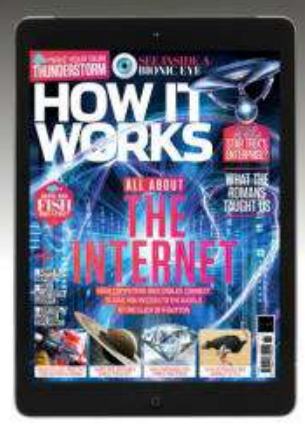

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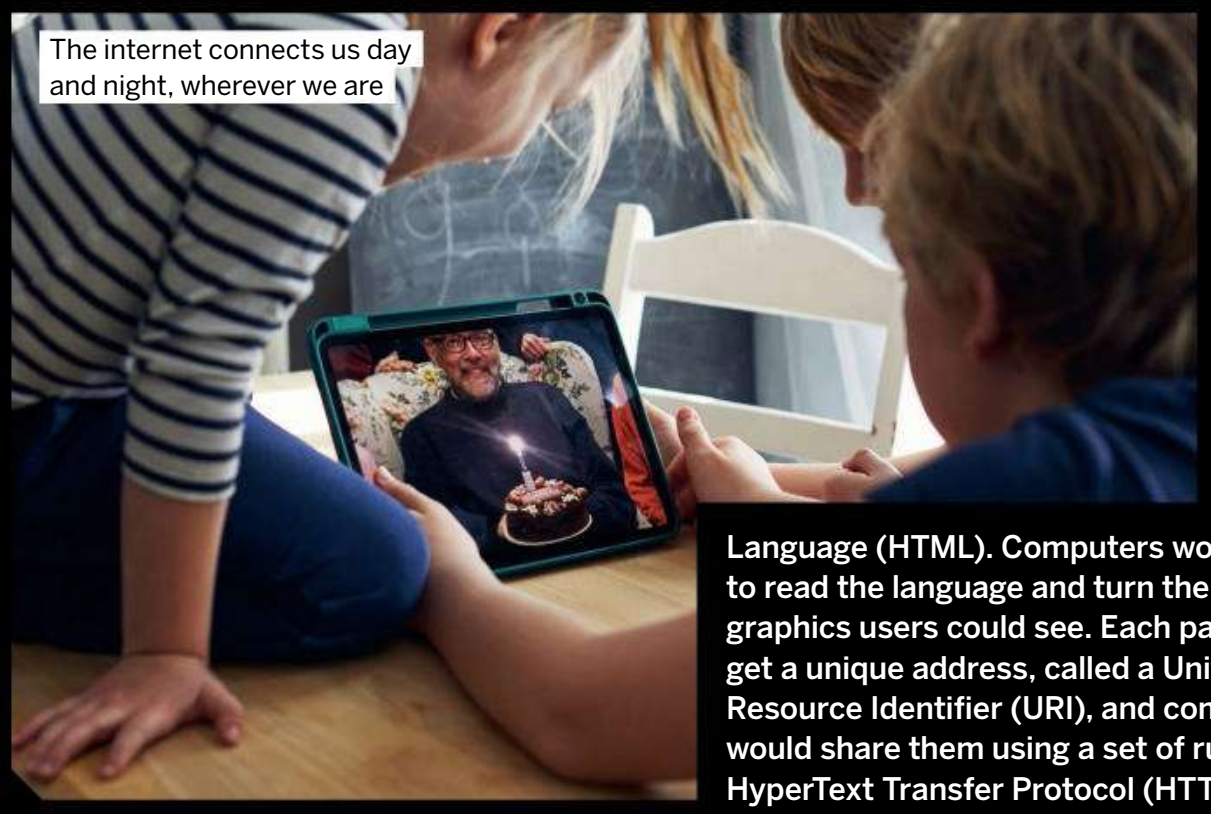
SPECIAL

# ALL ABOUT THE INTERNET

WORDS LAURA MEARS

Discover how you can access images and information all over the world – and even beyond – at the click of a button

**DID YOU KNOW?** Across the world, around 4.66 billion people use the internet – nearly 60 per cent of the global population



The internet connects us day and night, wherever we are

The internet is one of the greatest inventions in human history, revolutionising communication and changing the world forever. This vast network connects computers across the world via more than 750,000 miles of cables running under land and sea. It's our fastest method of communication, making it possible to send a message from London, UK, to Sydney, Australia, in just 250 milliseconds. Constructing and maintaining this global link has been a monumental feat of ingenuity.

Created in the United States in the 1960s, the internet was originally a response to the Cold War. President Eisenhower founded the Advanced Research Projects Agency (ARPA) to give a boost to the country's military technology. In need of a secure way to communicate across the country, scientists and engineers started developing a network of linked computers called ARPANET. The original aim was for two computers in different places to be able to share data. By 1969, that dream had become a reality. In the years that followed, the team linked dozens of computers together, and by the end of the 1980s this network contained more than 30,000 machines.

The earliest internet users were mainly researchers and military personnel. The network was complicated, and although it was possible to share files and messages, the interface was not user-friendly. In the early 1990s, a researcher called Tim Berners-Lee started building a layer on top of the internet to make it easier to access; it would become the World Wide Web. His idea was to make information available as pages, written in a shared language called HyperText Markup Language (HTML). Computers would be able to read the language and turn the pages into graphics users could see. Each page would get a unique address, called a Uniform Resource Identifier (URI), and computers would share them using a set of rules called HyperText Transfer Protocol (HTTP). Suddenly, users could see the internet, and they could interact with it without needing to know what was going on behind the scenes.

Since the invention of the World Wide Web, the internet has exploded. In 1993, CERN, where Berners-Lee invented the World Wide Web, made the technology freely available to everyone. This meant that anyone and everyone could add to it, creating their own pages and sharing their own content. Even now, no one owns the internet, although big tech companies wield a lot of its power. It's simply a collection of interlinked networks managed by companies, governments, research organisations and individuals. Google, Microsoft, Amazon and others have changed the way it works, but so too have amateurs creating content from their homes.

**Did you know?**

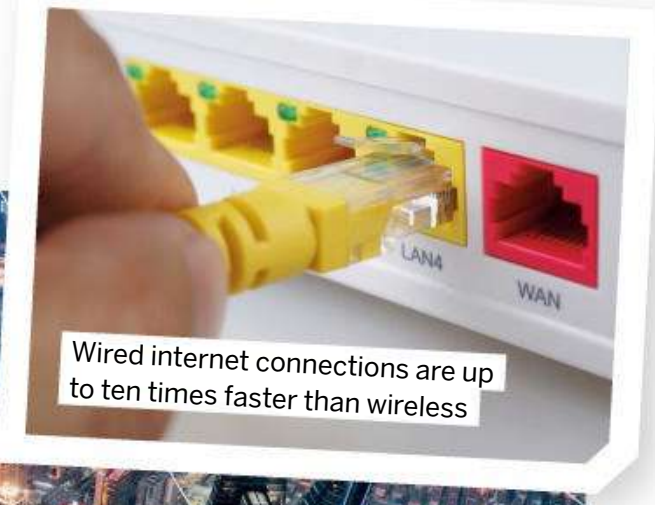
Google went public in August 2004, but it was founded in 1998

Since its inception, users have continued to expand the internet, sharing bigger and more complicated content. In 1993, there were fewer than 150 websites on the internet. Now there are almost 2 billion. This ever-growing web of connections has completely changed the way that people live, work and interact.

Pretty much the entire planet is connected to the internet

© Getty

# STEP BY STEP



Wired internet connections are up to ten times faster than wireless


The country with the most internet users is China, with a billion people online

The internet is a giant computer network, linking billions of machines together with underground cables. When you use it, you send messages via those cables asking for data stored on other machines. To make this possible, your computer and the computer you want to talk to need to speak the same language, so there's a set of rules that everyone agrees to use.

These are called TCP/IP, which stands for Transmission Control Protocol/Internet Protocol. TCP/IP makes the internet work a bit like a postal system. There's an address book that contains the identity of every device on the network and a set of standard envelopes for packaging up data. The envelopes must carry the address of the sender, the address of the recipient and details about the information packed inside.

The Internet Protocol (IP) part of the rules explains how the address system works. The Transmission Control Protocol (TCP) part explains how to package and send the data. All computers get an IP address when they connect to the internet, and they're all unique. You can find out yours by typing 'what's my IP' into Google. You'll notice that it's not very human-friendly. It either contains four numbers between 0 and 255, separated by full stops, or eight four-digit sequences separated by colons.

You might also notice that your IP address doesn't stay the same. At home you get your IP address from your internet service provider, but when you're out and about it might come from the Wi-Fi you've connected to in a coffee shop or from your phone company network. To load a website, your machine needs to know the IP address of the web server that contains the data. This is also a long string of letters and numbers, and it might change unexpectedly.

**Did you know?**
**The most popular social network is Facebook**

Luckily, there's a second address system that helps you guide your computer to the right place. Known as the Domain Name System, or DNS for short, it gives servers human-friendly names called domains. Your web browser can look these up to find out which IP address to use. Your computer can then make a connection to the server using a three-way handshake.

First, your computer sends a message to the server asking if it's ready to talk. It does this by sending an empty envelope with the word 'synchronise?' written on the front. If the server is ready, it writes 'acknowledge' on a new envelope and sends it back. Finally, your computer completes the connection by sending a third envelope that also says 'acknowledge'.

Now you're ready to start exchanging data. To do this, the server chops the content of the website into small pieces and wraps each one in its own envelope. On the outside it writes its own IP address, your IP address and a sequence number. That number tells your computer how to put the pieces back together. When your computer receives one of these envelopes, it checks it and sends a message back saying 'acknowledge' – this means 'I have received the data and everything looks fine'. If the server doesn't get an acknowledgement back from your computer after a set amount of time has passed, it assumes the envelope got lost or damaged and sends it again.

Once all the data is safely on your computer, the only thing left to do is close the connection. This involves another three-way handshake. One computer sends an envelope that says 'finish'. The other sends back 'acknowledge'. The first one replies with 'acknowledge', and then the connection closes.

**"To load a website, your machine needs to know the IP address of the web server that contains the data"**

## URL DISSECTION

**What do the different parts of a web address mean?**

**1 SCHEME**
This tells your browser what rules to use: 'http' is short for HyperText Transfer Protocol. The 's' means secure.

**2 AUTHORITY**
This tells your browser who you want to talk to. It's usually a domain name, but it can also be an IP address.

**3 RESOURCE NAME**
This is the name of the resource you want it to access – in this case a web page about computer history.

**4 PATH TO RESOURCE**
Words separated by forward slashes make up the path to the resource you are looking for on the web server.

**5 HOSTNAME**
This label identifies the computer or server that your request is going to. The convention for web servers is 'www'.

**DID YOU KNOW?** On average, internet users spend seven hours online each day. Top activities include shopping and social media

# HOW DO WEBSITES WORK?

**What happens when you type www.livescience.com into your browser and hit enter?**

### 1 USER
When you type the web address, you're telling your browser to make a request to the **LiveScience** web server.

### 2 TCP CHANNEL
Your web browser opens a connection called a TCP channel. Its job is to link you to **livescience.com**.

### 3 HTTP REQUEST
Your browser then sends an HTTP GET request. It's asking to GET the contents of the **LiveScience** homepage.

### 4 MODEM
Your computer passes the digital request to your modem. It takes the request and converts it into an analogue message that can pass through underground cables.

### 5 ROUTER
The request enters a network of cables underground. It passes through a series of computers called routers, which send it on towards the **LiveScience** web server.

### 6 DOMAIN NAME SERVER
The **LiveScience** web server has a unique address called an IP address. The domain name server keeps a record of that address to help the network work out where to send your request.

### 7 WEB SERVER
The **LiveScience** web server stores all the pages and data for **livescience.com**. When it receives your GET request, it sends the data back to your computer.

### 8 PACKETS
There's a lot of content on a **LiveScience** web page: text, images and even video. It's possible for the web server to send it all at once, but if anything goes wrong it needs to send the whole lot again. To get around this, the server splits the content into small parcels called packets. They travel through the network separately, often via different routes. Your browser checks each packet for errors and reassembles them to build the web page. If one packet gets lost or damaged, the server only has to send a small amount of data again.

**AR zone** SCAN HERE

Layers of rules connect your devices to the internet

© Getty / Illustration by Adrian Mann

# WHAT IS THE INTERNET?

Most of the content on the World Wide Web lives on servers in data centres

This giant network can seem almost ethereal. For the most part we connect to it without wires, sending and receiving data as if from thin air. We can scroll through cat pictures in the middle of a field and stream movies straight from the cloud. But despite that airy feeling, the nuts and bolts of the internet are very solid and very down to Earth. At its core, it's a network of billions of miles of wires end-to-end, and millions of computers.

Your internet connection begins at the modem that's set up in your house. It connects via a wire to a socket in the wall, which links to a box outside. That box connects via still more wires to a network of cables under the ground. Together they convert radio waves to electrical signals to fibre-optic pulses and back again.

At every connection point in the underground network, there are junction boxes called routers. Their job is to work out the best way to pass data from your computer to the computer you're trying to communicate with. They use your IP addresses to work out where the data should go. The internet is so massive, and changes so rapidly, that it would be impossible for every router to know the IP address of every computer, so each one only cares about its local network. They each maintain an address book called a routing table. It shows the paths through the network to all the local IP addresses.

If a message arrives for a computer that the router doesn't recognise, it passes it on to a router higher up in the local network. If that router doesn't recognise the IP address either, it passes it up again. Eventually, it reaches the top of the network: the backbone. This is the motorway of the internet. Its job is to send traffic around the world, across both land and sea. The data passes from backbone to backbone until it reaches the network closest to its destination. Then it travels down through the layers of local routers until it arrives at the computer with the matching IP address.

These destinations are often data centres, buildings filled with rack upon rack of powerful computers called servers. They contain and manage everything from your social media profile to your email account, your bank and your holiday photographs.

## TYPES OF CABLE

**Most of the data you send and receive over the internet travels by cable**

**COAXIAL CABLE**

Often known as coax, these cables are thick and round, with layers of insulation surrounding a single central core. They can transmit ten megabits of data per second.

**TWISTED PAIR**

Also known as ethernet cables, twisted pairs were specifically made for connecting computers. Each cable contains four pairs of twisted wires, transmitting ten gigabits per second.

**FIBRE**

The fastest cables don't carry data as electricity; they carry it as beams of light. At their centres they have a glass core capable of transmitting up to 100 gigabits per second.

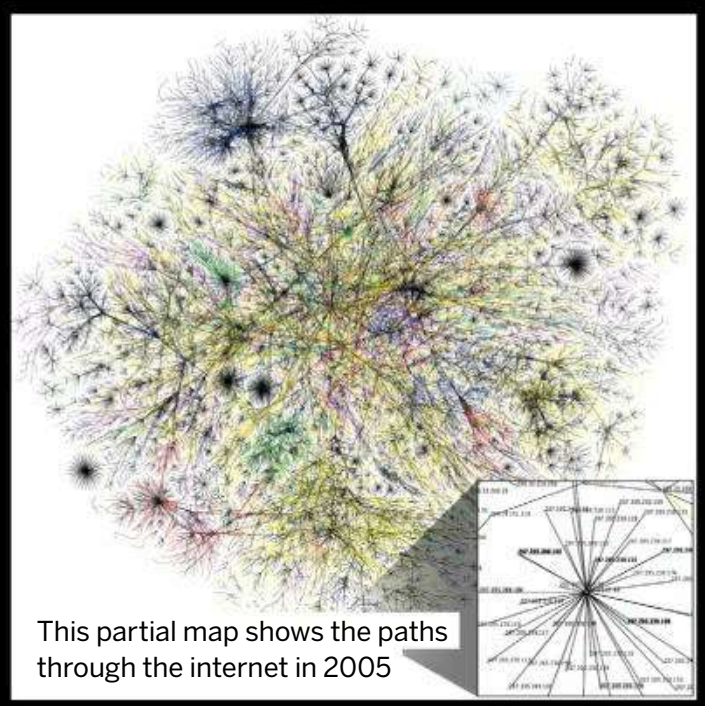
**Did you know?**

**The first subsea cable was buried in 1950**

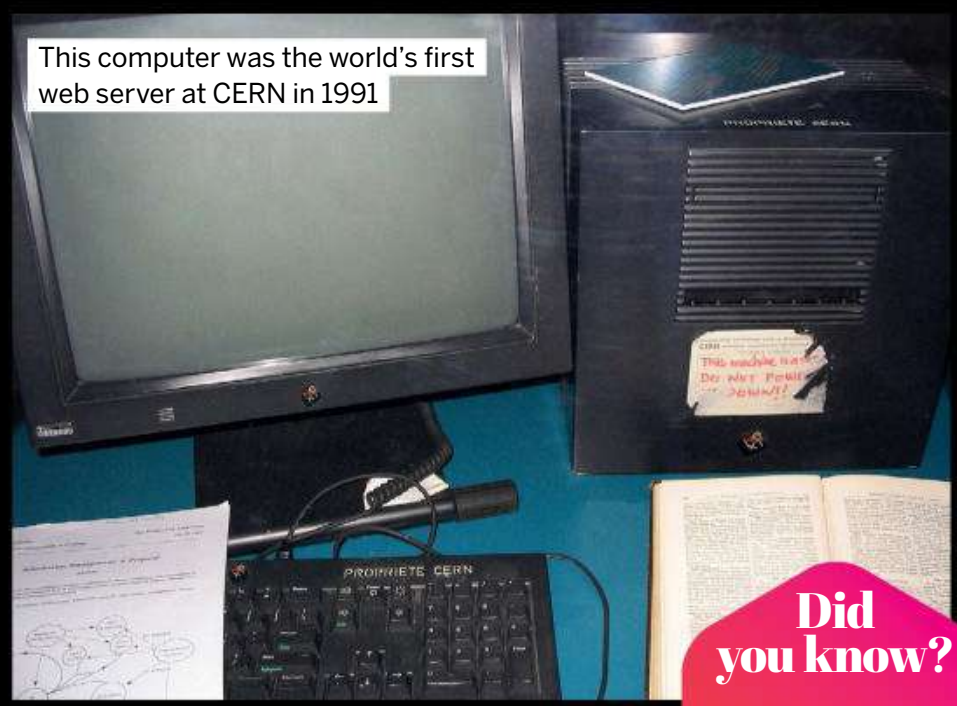
## UNDERWATER CONNECTIONS

**Have you ever wondered how an email from the US makes its way to Germany? The answer is under the sea. Snaking beneath the world's oceans are miles of submarine optical fibre. The cables run from coast to coast and from continents to islands, connecting everywhere except Antarctica in a literal World Wide Web. About the width of a sausage, each cable contains strands of glass that transmit data as pulses of light. Those strands are wrapped in layers of insulation and buried beneath the seafloor by ships carrying specialist ploughs. This helps to protect them from everything from corrosion to shark bites.**

**DID YOU KNOW?** Google handles over 3.5 billion searches every day. More than half come from mobile phones



This partial map shows the paths through the internet in 2005



This computer was the world's first web server at CERN in 1991

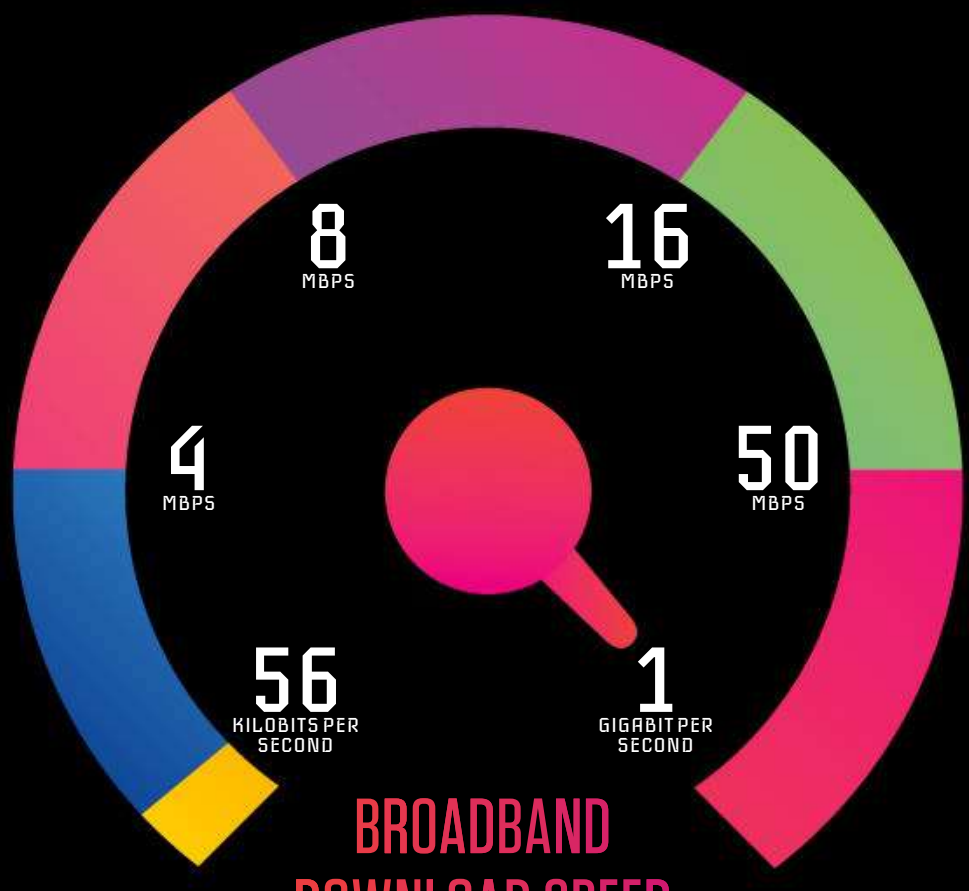
**Did you know?**

Over 1.8 billion websites exist on the internet

# NEED FOR SPEED

When it comes to internet speed, how much data you can download in one second comes down to one thing: bandwidth. To surf the web, check your email and update your social media, 25 megabits per second (Mbps) is enough. But if you want to watch 4K movies, live stream video or play online multiplayer games, you might need speeds of up to 100 megabits per second or more.

Your download speed depends on one main factor: the quality of the underground cables that link you to the rest of the world. Fibre-optic cables send data much faster than their copper counterparts, and your home internet is limited by the infrastructure available in your area. Jersey has the highest average bandwidth in the world. The little British island off the coast of France boasts average download speeds of over 274 megabits per second. Turkmenistan has the lowest, with download speeds barely reaching 0.5 megabits per second.




## BROADBAND DOWNLOAD SPEED

SPEED 56 KILOBITS PER SECOND

TIME TAKEN TO DOWNLOAD A MOVIE

### 3 DAYS, 13 HOURS, 13 MINUTES

In the early days of the internet, data had to travel over copper phone lines. Downloads were painfully slow, making video-sharing practically impossible.

SPEED 4 MBPS

TIME TAKEN TO DOWNLOAD A MOVIE

### 1 HOUR, 12 MINUTES

3G mobile internet connections provide enough bandwidth to surf the web and send email, but downloading large files takes hours.

SPEED 8 MBPS

TIME TAKEN TO DOWNLOAD A MOVIE

### 36 MINUTES

Average download speeds for 4G mobile internet allow one user to surf or stream on the move. A strong connection can boost bandwidth to 40 megabits per second.

SPEED 16 MBPS

TIME TAKEN TO DOWNLOAD A MOVIE

### 17 MINUTES

Standard broadband connections and older satellite connections offer enough bandwidth for a couple of users to browse the web and shop online.

SPEED 50 MBPS

TIME TAKEN TO DOWNLOAD A MOVIE

### 6 MINUTES

Fibre broadband and modern satellite connections offer speeds fast enough for multiple users to stream video content and play games at the same time.

SPEED 1 GIGABIT PER SECOND

TIME TAKEN TO DOWNLOAD A MOVIE

### 17 SECONDS

The fastest home fibre broadband allows five or more users to download massive files, watch 4K movies and play competitive games simultaneously.

## 5 FACTS SOCIAL MEDIA BY NUMBERS

**1 FACEBOOK HAS THE MOST USERS**
Each day, 1.9 billion people sign into Facebook. They spend almost an hour there each and together upload more than 300 million photos.

**2 YOUTUBE HAS THE MOST VIDEO**
When it comes to video, YouTube is the top social media platform. Users add 500 hours of new content every single minute.

**3 SIX DEGREES IS THE OLDEST**
The first social media platform was Six Degrees. Created in 1996, it was the forerunner to Friendster, Myspace and Facebook.

**4 TIKTOK IS THE MOST POPULAR APP**
When it comes to social media apps, TikTok was the worldwide favourite in 2020. It had over 850 million downloads.

**5 WHATSAPP RULES MESSAGES**
This encrypted messaging app is the most popular. It has 2 billion users a month, sharing more than 100 billion messages a day.

© Alamy / Getty / Wiki: The Opte Project; Coolcaesar

# THE FUTURE OF THE INTERNET

Portable modems and antennae allow satellite internet access in remote locations

In 2019, SpaceX launched 60 satellites. They are set to become part of a constellation of more than 12,000. Known as Starlink, the project aims to bring high-speed internet to every corner of the planet. As it stands, fast internet access is only available in places with fibre-optic cables. In remote locations, communications satellites provide links to the internet, but the connections are notoriously slow. These satellites traditionally fly high above Earth. They sit in geostationary orbit, moving at the same speed as Earth's rotation. They have a wide view of Earth's surface and always hover over the same point on the ground. This makes it easy for satellite dishes to find them. The downside is that getting data to them takes time.

SpaceX wants to change that by surrounding Earth in a cage of low-orbiting satellites. Individually, they won't see as much of Earth's surface, and they won't always hover above the same spot, so there will need to be thousands of them to ensure complete coverage of the globe. But because they fly low, it will cut the time it takes for a signal to travel from the ground to space and back again.

Achieving this is no mean feat. The closer a satellite is to Earth, the more drag it will experience from the edges of the atmosphere. To get around this, SpaceX has designed the satellites to look like sharks, with a knife-like edge that cuts through the wind. Each one weighs just 250 kilograms and works a bit like a router. Its job is simply to receive signals, work out where they're going and pass them on. On the ground, users will have special dishes that lock on to whichever satellite is closest. But the project is not without controversy.

> "SpaceX wants to surround Earth in a cage of satellites"

Each satellite has a solar array that sticks out like a wing. At sunrise and sunset, these catch the light, making them glint like shooting stars. As the constellation moves overhead, it leaves streaks on telescope images, obscuring the stars and planets behind. SpaceX has been working with astronomers to minimise the impact by shading and tilting the satellites to reduce the light reflected back towards Earth.

The satellites also pose a potential threat to other orbiting objects. They're already responsible for over half of the close encounters in Earth's orbit, and that proportion is only set to rise. In December 2021, the Chinese government lodged a formal complaint with the United Nations after two near misses with the Chinese Space Station Tiangong. And with at least 11 other companies already entering the satellite constellation race, space is likely to get more complicated and more crowded in years to come.

Long-exposure images show Starlink satellites streaking across the night sky

## HOW STARLINK WORKS

**Can a network of satellites provide high-speed broadband to every corner of the globe?**

**1 GROUND STATION**
Fibre-optic cables send data from the internet to the ground station.

**2 LOW ORBIT**
The ground station sends the data into space, past objects in low-Earth orbit, like the ISS.

**3 UPLINK**
The nearest Starlink satellite receives data from the ground station.

**4 SATELLITE NETWORK**
The data travels through the Starlink network until it reaches the satellite closest to the user.

**5 HIGHEST ORBIT**
The signal never travels higher than 621 miles, avoiding other communications satellites.

**6 DOWNLINK**
The satellite sends the data signal back down to Earth.

**7 SATELLITE DISH**
A satellite dish receives the signal anywhere in the world.

**8 MODEM**
A modem connected to the satellite links the user's devices to the internet.

## CONNECTING THE WORLD

**1966**
The US Defence Agency funded the Advanced Research Projects Agency Network, or ARPANET. Its primary mission was to create the internet.

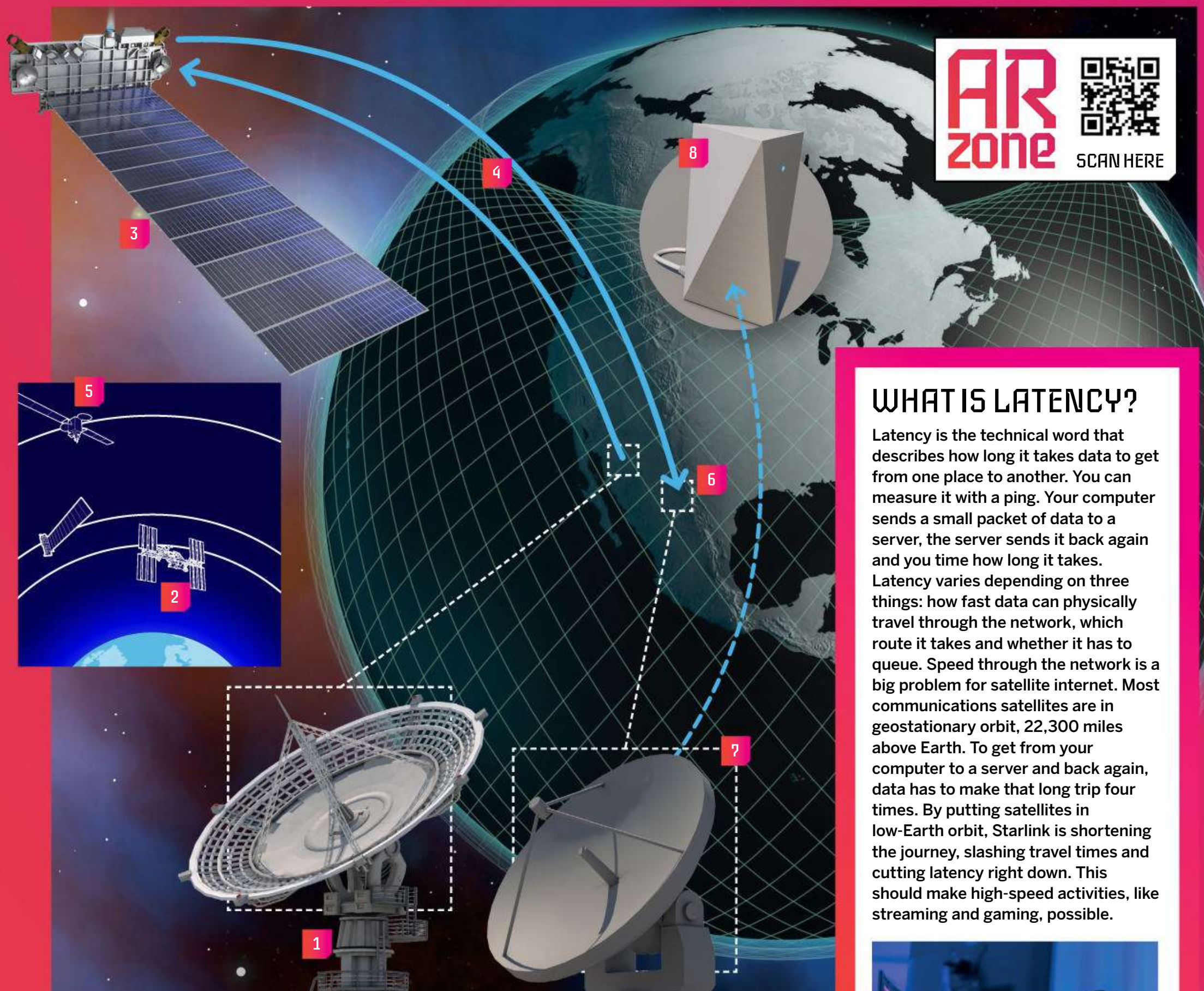
**1969**
Researchers sent the first ARPANET message. It was supposed to say 'login', but the system crashed after the letters 'lo'.

**1971**
Ray Tomlinson invented email and email addresses. He chose to put the @ symbol between the username and the location.

**1983**
ARPANET split into two networks: one for military communication and another for everything else. This was the birth of the internet.

**1989**
Tim Berners-Lee invented the World Wide Web, a way to connect documents on the internet together with hyperlinks for ease of use.

**DID YOU KNOW?** The average person spends 2 hours and 22 minutes a day looking at social media




## WHAT IS LATENCY?

Latency is the technical word that describes how long it takes data to get from one place to another. You can measure it with a ping. Your computer sends a small packet of data to a server, the server sends it back again and you time how long it takes. Latency varies depending on three things: how fast data can physically travel through the network, which route it takes and whether it has to queue. Speed through the network is a big problem for satellite internet. Most communications satellites are in geostationary orbit, 22,300 miles above Earth. To get from your computer to a server and back again, data has to make that long trip four times. By putting satellites in low-Earth orbit, Starlink is shortening the journey, slashing travel times and cutting latency right down. This should make high-speed activities, like streaming and gaming, possible.

Low latency is crucial in preventing lag in online games

**1991**

The first-ever website went live. You can still visit it today at **info.cern.ch**.

**1992**

Dial-up brought the internet into people's homes for the first time, using telephone lines to download data up to 56Kbps.

**2000**

The introduction of asymmetric digital subscriber line (ADSL) broadband increased home internet speeds to 512Kbps.

**2008**

The first fibre broadband made 50Mbps download speeds possible, paving the way for streaming.

**2009**

The introduction of 4G internet brought broadband-like download speeds to mobile phones.

© Getty / Wiki: Miles.world; Paul Clarke; Streepjescode / Illustration by Adrian Mann

# THE INTERNET BY NUMBERS

## 390 MILLION

Instagram followers total nearly half a billion

## 60 MBPS

The average broadband speed worldwide

## 2,670

There are thousands of data centres in the US alone

## THE FIRST-EVER MUSIC DOWNLOAD HAPPENED IN 1994

## THE MOST GOOGLED WORDS IN 2021 WERE 'AUSTRALIA VS INDIA'

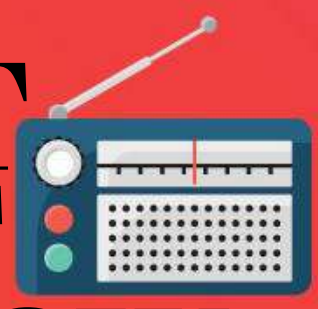
## 670,000 SQUARE METRES

The world's largest data centre, the Citadel, covers over 165 acres

## 21 NOVEMBER 2020

This was the busiest day ever on the internet

## THE FIRST INTERNET RADIO SHOW AIRED IN 1993



## 30 MBPS

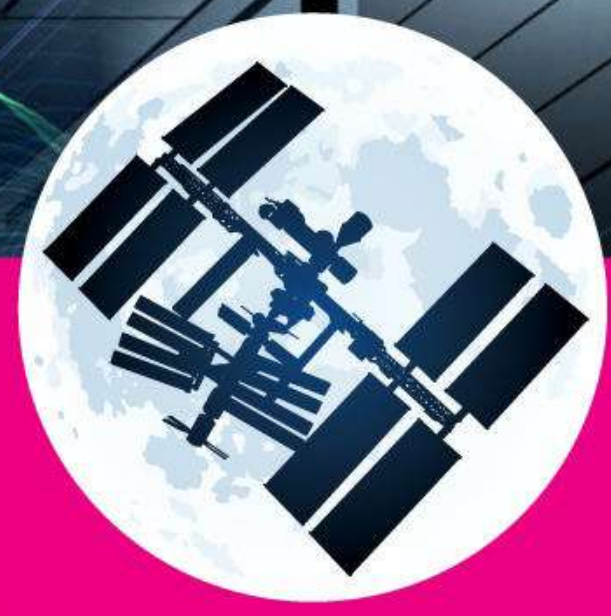
The average mobile internet speed is about half that of home broadband

**DID YOU KNOW?** The World Wide Web is only 12,000 days old – that's less than 35 years

# THE MOST GOOGLED ANIMAL WORLDWIDE IS THE CAT

## 6.5 BILLION

The number of mobile broadband subscriptions worldwide

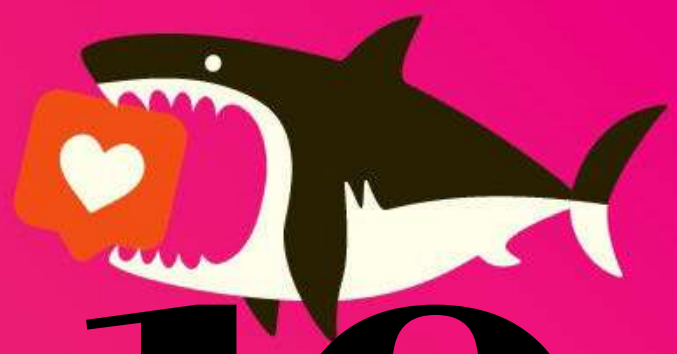


## 600 MBPS

The broadband speed on the International Space Station

## 2,800 METRES

The deepest live internet broadcast



## 10 BILLION

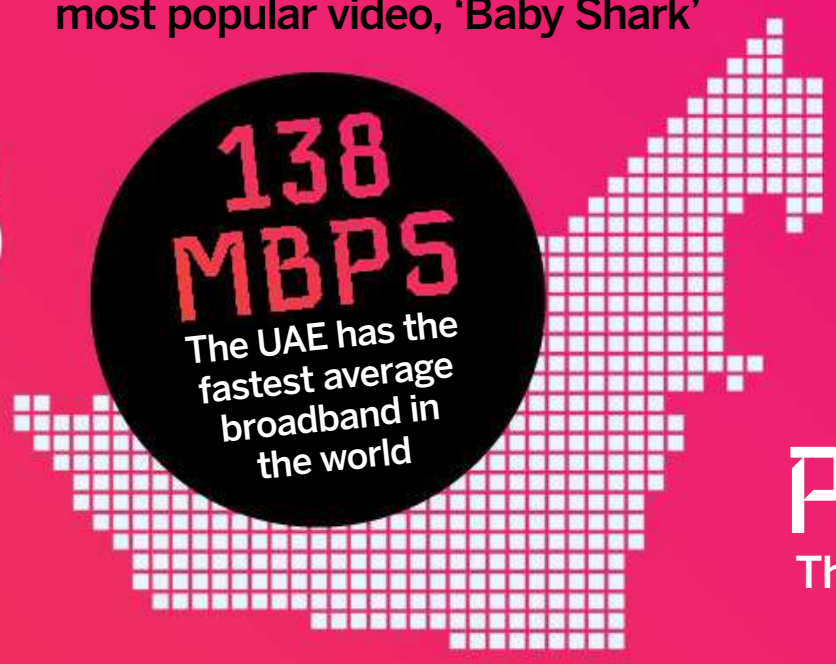
Times people have watched YouTube's most popular video, 'Baby Shark'

## 92 TERABITS PER SECOND

The capacity of the world's most powerful router

## 237 MILES

The longest ever broadband wireless signal




## 319 TERABITS PER SECOND

The current world record internet speed

## 882MBPS

Haul Fryn, Swansea, is the street with the UK's fastest broadband

## 64.2 ZETTABYTES

The world creates and consumes over 64 trillion gigabytes of data annually

©Getty

A fire rescue team using the jaws of life to cut a car's frame

Firefighters using the spreader tool to break open a car

# WHAT ARE THE JAWS OF LIFE?

## These emergency tools are a firefighter's valuable companion during crash recoveries

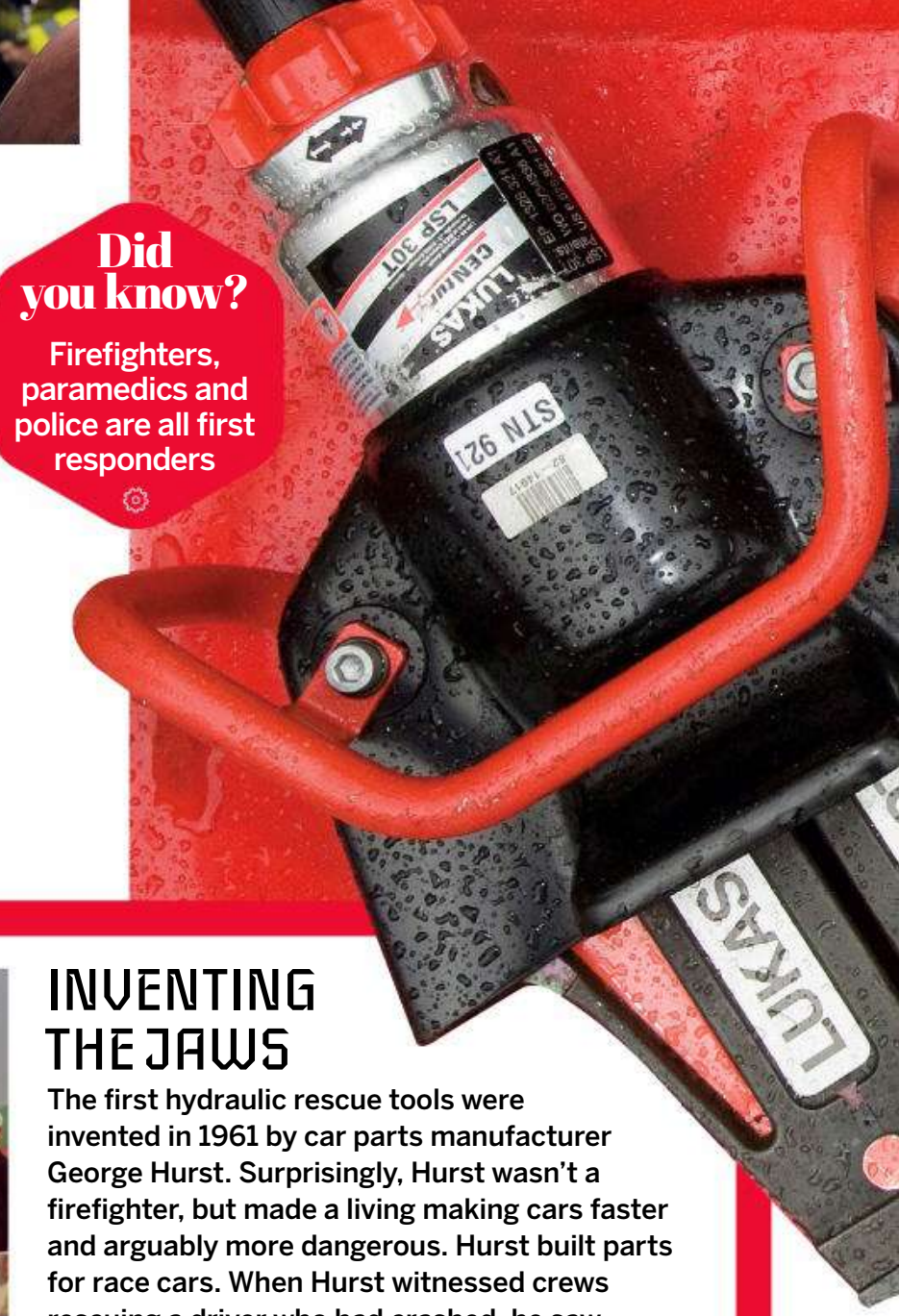
WORDS **AILSA HARVEY**

Most vehicles on the road are built with cages for protection. Their strong, durable frames are designed to prevent as much damage to their passengers as possible, even during a collision. However, in the most severe incidents, these frames can be flipped, compressed and crushed. For those inside the car during an accident, this can mean being pinned to the ground, impaled or trapped by the metal.

When first responders arrive at the scene, their main goal is to release the car's passengers quickly and safely so that they can be treated. Some people may have sustained serious injuries, and any movement of the crashed car can cause further injury. The strongest tools are required in these cases, to smoothly slice through any material obstructing a crash victim's exit from the vehicle. The jaws of life are the favoured hydraulic tool for this job. This heavy piece of equipment can effortlessly widen openings to the vehicle, cut car frames apart and lift crushing weights from passengers.

**Did you know?**

**Firefighters, paramedics and police are all first responders**



Jaws of life inventor George Hurst, pictured in 1967

### INVENTING THE JAWS

**The first hydraulic rescue tools were invented in 1961 by car parts manufacturer George Hurst. Surprisingly, Hurst wasn't a firefighter, but made a living making cars faster and arguably more dangerous. Hurst built parts for race cars. When Hurst witnessed crews rescuing a driver who had crashed, he saw flaws in the existing tools. They were too slow and not very efficient at cutting into the car.**

**In 1961 he patented the first hydraulic rescue tool, which he named the Hurst Power Tool. A decade later, Hurst improved the tool to make it lighter to carry, and during the 1970s it was embraced by firefighters. As the hydraulic tool had saved many victims from the 'jaws of death', the name was revised, becoming the 'jaws of life'.**

**DID YOU KNOW?** Combination tools allow firefighters to cut and spread cars with a single piece of equipment

# A TRINITY OF TOOLS

**Cutters, spreaders and rams are used to pull apart vehicles**

## CUTTER

These are like giant scissors. Cutters can slice through metal easily and are used to remove any obstacles that block rescuers from getting to a trapped person. This tool creates larger openings to improve access to crash victims.

## RAM

This giant rod extends forward to push away any heavy materials that could be trapping someone. The ram can be used in the door frame to push the dashboard up and away from a driver or passenger.

## SPREADER

This is the opposite to a cutter, as the hydraulic force is used in the opposite direction. Used mainly to alter compressed car frames, the spreader starts in a closed position and opens. As the two halves of the spreader separate, they can push apart steel.

Fires are common after car accidents, so hydraulic equipment cannot be flammable

# HOW THE HYDRAULICS WORK

**How do these tough tools push, cut and ram through a car's high-strength materials? Hydraulic machines such as the jaws of life convert the potential energy stored in high-pressure liquid into kinetic energy. Oil is the most common fluid for these machines, but the jaws of life use phosphate-ester fluid instead. This is a fire-resistant alternative that doesn't conduct electricity, making rescue operations safer. When in use, a piston inside the tools pushes the liquid downwards. As an incompressible liquid enters a small space, the pressure is greatly magnified. This effect can be created with a small volume of liquid. The liquid transfers this force to another piston, which is pushed upwards. It's this force that moves the arms or blades of spreaders and cutters.**

© Alamy / Getty

# HOW BLUETOOTH WORKS

Wireless headphones are just one of the technologies which have been revolutionised by Bluetooth

## Inspired by a Nordic king and harnessing the power of radio, here's how wireless connectivity reshaped our electronic ecosystems

WORDS **MARK SMITH**

If you look around the room you're in right now, chances are you can spot at least half a dozen electrical devices. But imagine if they all had to be joined together by wires? Picture the wire snaking along the floor from your smartphone to your speaker, or connecting your console to your game controller, meaning you could never sit more than a couple of metres away from the screen. A world of electronics connected by wires wouldn't just be untidy, but a potential health-and-safety nightmare, too. That's where Bluetooth comes in. We've all heard of it – but what exactly is it?

Bluetooth is a method of short-range wireless communication between electronic devices that harnesses the power of radio waves. First developed in the late 1990s, the technology has become an increasingly popular way of solving the problem of more and more electrical devices needing to be connected, without having to link everything together with wires.

But if you look at the remote control you use to switch the channel on the TV, you might rightly ask yourself why Bluetooth was such a big deal. After all, connecting devices with invisible signals had been done before. The problem with remote controls – which use infrared signals – is that they need to maintain what is called 'line of sight'. If something is standing between the transmitter and receiver, it won't work.

**"Imagine if they all had to be joined together by wires?"**

Because Bluetooth uses radio, obstacles are no longer a problem, but it has a relatively short range of around ten metres. Since its creation in the late 1990s, the technology has become more and more refined and widely used, with the 4 billionth Bluetooth device being shipped in 2020.

Modern cars are equipped with Bluetooth so we can harness our phone's features, such as GPS and music players

The iconic Bluetooth symbol has become a familiar sight on our mobile devices

The Bluetooth headset has become a very recognisable piece of equipment

### BROADCASTING BANDWIDTH

**The secret to Bluetooth is good old-fashioned radio, but not quite as we know it. The main function of radio when used for broadcasting, or when we use it to broadcast mobile phone signals – is distance. After all, a radio station wants to be heard far and wide, while mobile phone signals have to reach the nearest phone tower so they can be relayed to a receiving handset. But Bluetooth is much less powerful than that, with a range of only a few metres. The radio spectrum stretches from 3 Hz to 3,000 GHz. The lower the frequency, the longer the range, but also the lower the data rate and quality it can support. Bluetooth operates at 2.4 GHz, which gives it the right balance between range and data quality. The other benefit of this frequency is that it's available around the world, making it a standard bearer for low-power wireless connectivity.**

**DID YOU KNOW?** The technology was named for Harald Bluetooth, the 10th-century Danish king who unified Denmark and Norway

# CONNECTING AN ECOSYSTEM

**Bluetooth is underpinned by a complex web of radio signals**

**1 SLAVE**
The device which receives the Bluetooth signal is called the 'slave'.

**2 SYNCHRONISATION**
The two Bluetooth devices have to match each other's radio frequency to communicate.

**3 MASTER**
The device which initiates a Bluetooth connection with another is called the 'master'.

**4 PICONET**
This tiny network contains a minimum of two devices. When two piconets are connected by a device, it's called a scatternet.

**5 RADIO SIGNAL**
Low-powered radio signals are sent and received.

**6 BUILT-IN CHIPS**
A Bluetooth-enabled device includes a chip to send and receive signals.

**Did you know?**
The SIG has grown to over 36,000 members

## MOBILE ORIGINS

Bluetooth traces its beginnings back to the 1990s. It was conceived by Dr Jaap Haartsen at Swedish mobile giant Ericsson. Things really stepped up in September 1998 when the Bluetooth Special Interest Group (SIG) was formed to develop and promote the technology. The group released Bluetooth 1.0 in 1999, and a year later it began to be used in mobile phones and desktop computers, making its way to laptops and printers in 2001. In the middle of the decade, the Bluetooth headset – which allowed people to communicate hands free – became a common sight.

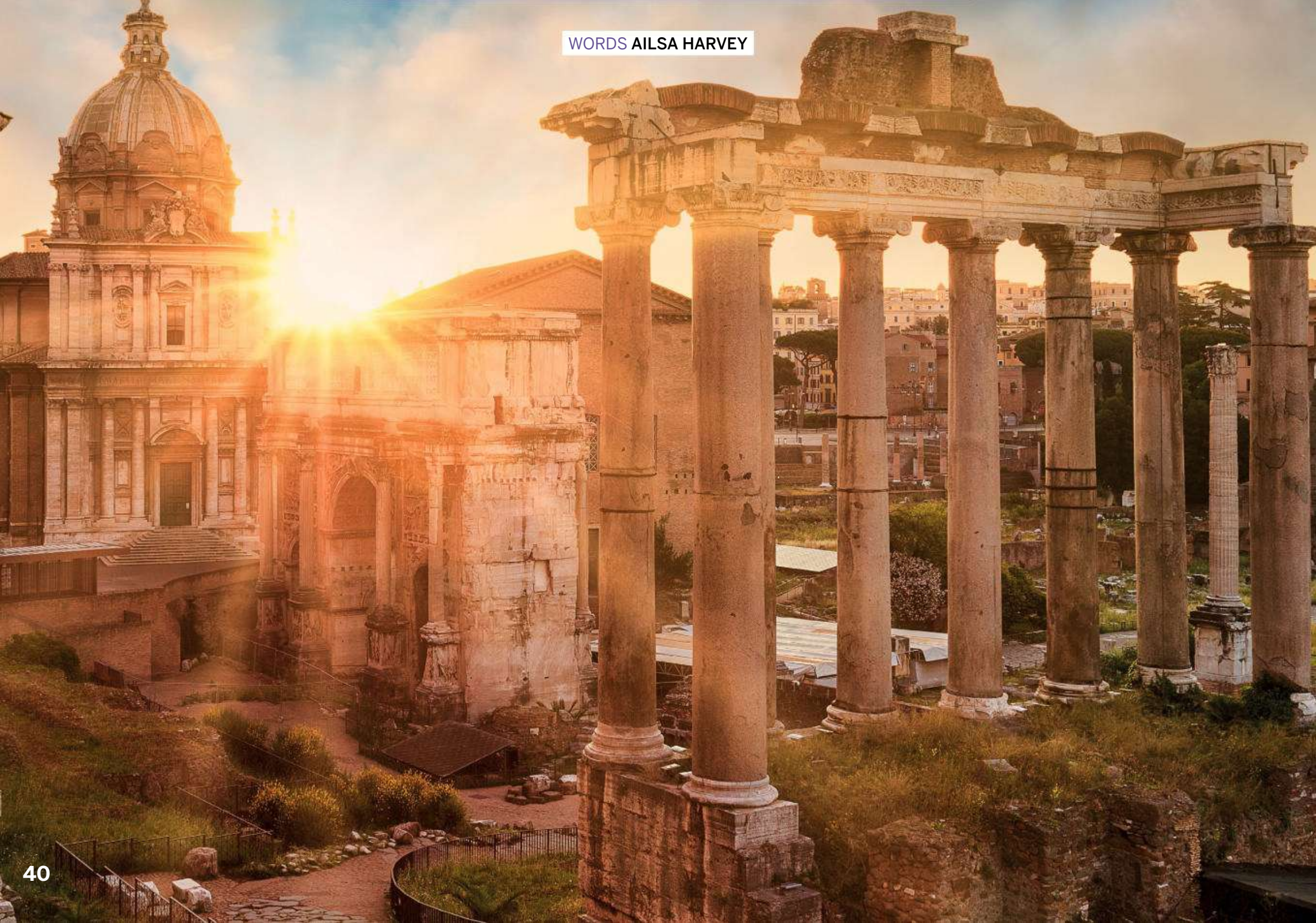
Bluetooth is used to connect all of our electronic devices together

© Getty

# WHAT THE ROMANS TAUGHT US

## How ancient Roman technologies have influenced the modern world

WORDS **AILSA HARVEY**



**DID YOU KNOW?** A city that includes 'chester', 'caster' or 'cester' is likely Roman – derived from 'castrum', Latin for 'fort'

With an empire that dominated most of Europe, western Asia, northern Africa and the Mediterranean, the Romans held enormous power and influence. From the 8th century BCE – when Rome was founded – to the empire's collapse in the 5th century CE, the Romans developed effective ways to build and maintain large communities. Although millennia have passed, the masterful work of the Romans can still be seen today.

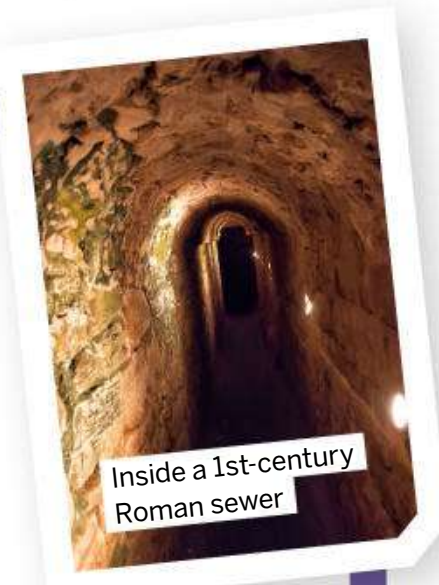
Their ability to utilise the resources they uncovered was impressive. Proving to be expert engineers, they used water and their knowledge of physics to produce energy for mills. On farmland, they taught the agricultural world how to maximise field yields. Crop rotations were established by the Romans, who invented the 'food, feed, fallow' system. By splitting farms into these three allotments, it ensured there were always crops ready to pick.

Some of the lessons we've learned from the Romans were their own inventions, while some were adopted from other cultures into the growing Roman Empire. For example, the Romans may not have invented the calendar, but the widespread use of their calendar has given the world a way to track passing time. From their own unique innovations to techniques they improved, here are some of the lessons the Romans helped teach the world.

## WHAT TO DO WITH OUR WASTE

**Ancient Rome was home to some of the world's first sewer systems. These underground waterways were first installed around 500 BCE and consisted of giant carved-stone tunnels. Today, many city sewers bear resemblance to those of ancient Rome – but their purpose may have been different. In the modern world, sewers' main function is to carry unsanitary waste away from urban areas. In ancient Rome, however, their main role was to remove the excess water that could flood the streets.**

**Some homes were connected directly to the Romans' covered drainage system. Other households simply tipped their sewage into the streets, but the streets were then washed to move waste into the sewers. Once there, it was contained in extensive tunnels, which the sewage travelled through until it reached nearby rivers. The architecture of sewers hasn't changed too much since these ancient builds. In fact, the 'Greatest Sewer' of ancient Rome is still in use today.**

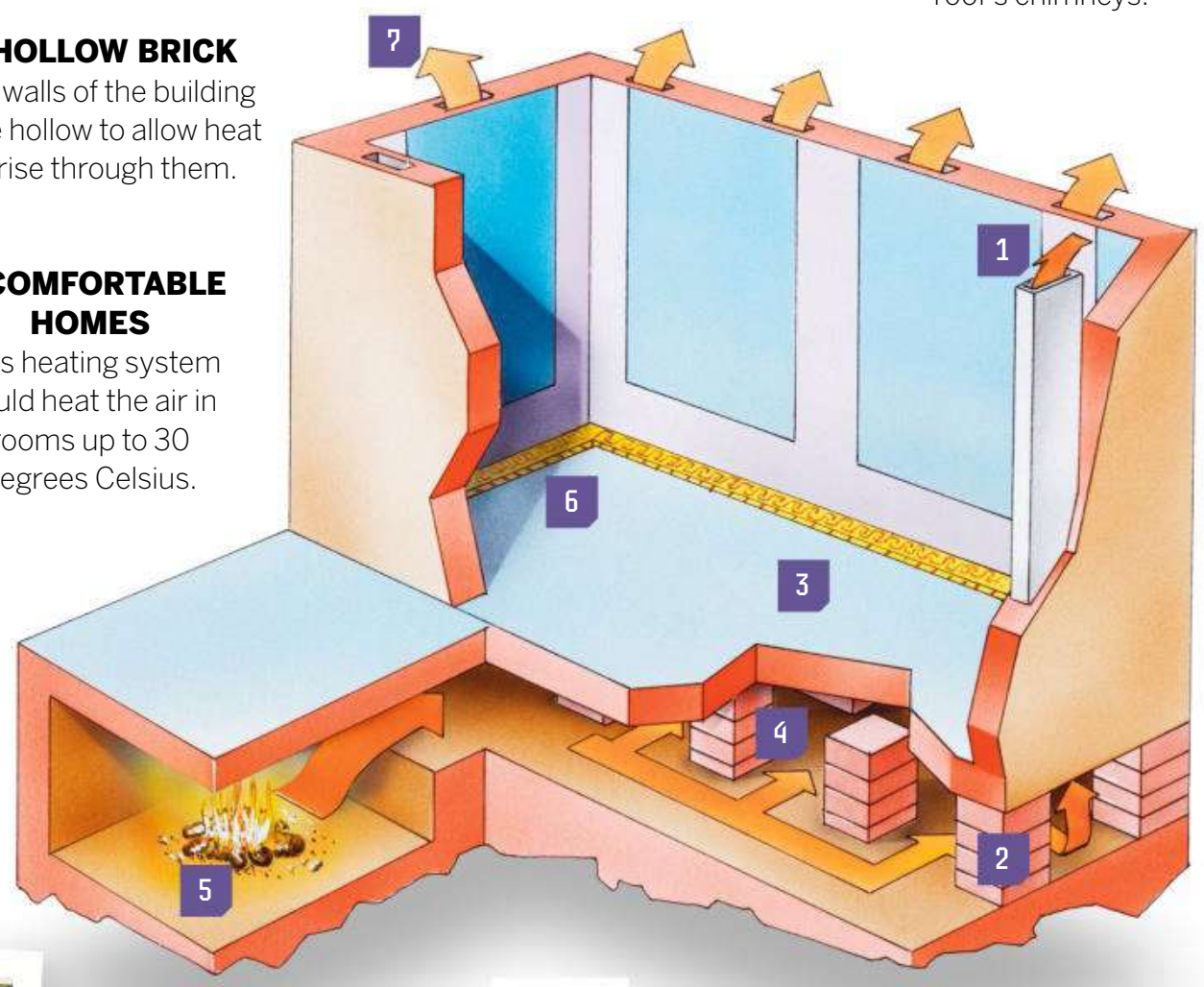

Inside a 1st-century Roman sewer

**Did you know?**

Servants were used to keep hypocaust systems operating

## HOW TO HEAT OUR HOMES

**The Romans invented the hypocaust system – an early method for efficiently distributing heat**




**1 SMOKE PASSAGE**
Cavities in the walls were essential to stop a buildup of smoke in the home. Smoke travelled vertically, released through the roof's chimneys.

**7 HOLLOW BRICK**
The walls of the building were hollow to allow heat to rise through them.

**6 COMFORTABLE HOMES**
This heating system could heat the air in rooms up to 30 degrees Celsius.

**5 FURNACE**
People were required to keep wood burning in the furnace, releasing heat.

**4 HEAT CIRCULATION**
The gaps between the stacks of brick created passages for hot air to spread horizontally.

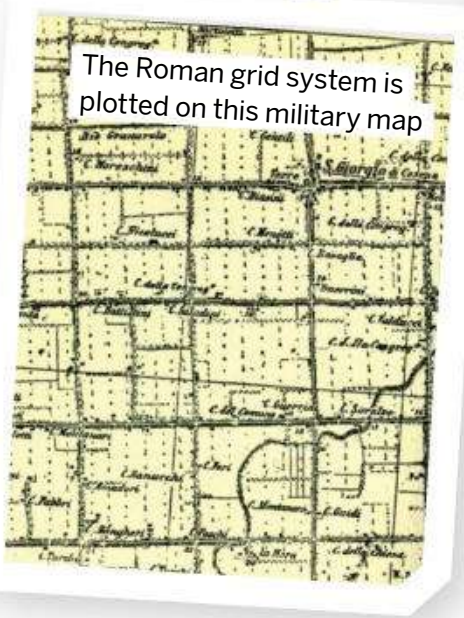
**2 CHAMBER SYSTEM**
Below the ground, brick pillars called pilae supported the building.

**3 TRANSFORMED BATHS**
Romans are famous for their baths. While early Roman baths were heated by natural hot water springs, hypocausts were also used from the 1st century.

## HOW TO PLAN OUR CITIES

**The grid layout of cities – also called centuriation – was one of the formats the ancient Romans adopted to divide and measure their land. The grid, which organised land into conquered territories, today organises large cities into functioning roads and streets.**

**The Romans were highly skilled at turning bare land into built-up cities as many towns under the Roman Empire were expanded and redeveloped. The design may seem simple today, but before the Romans produced mass grids, buildings and other town features often just followed the shape and geology of the land. Their criss-crossing street layouts created central squares for trading, called 'insulae'. This structure inspired the next city planners.**


The Roman grid system is plotted on this military map

© Getty / Wiki: Nerijp

# AR ZONE

## THE SECRET TO LASTING CONCRETE

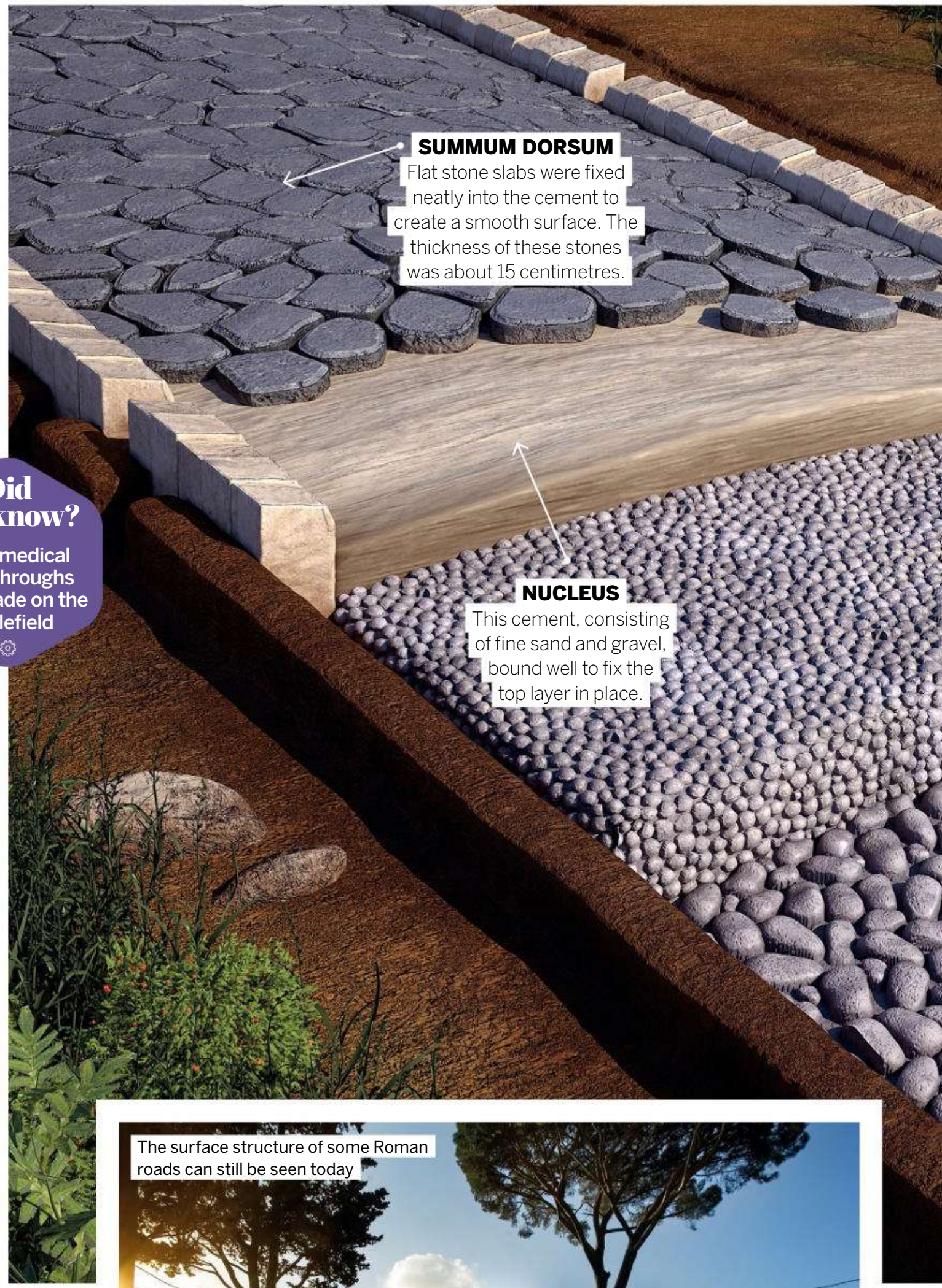
**Usually advancements in technology and knowledge mean that human-made items are continually being improved over time. However, the concrete made by the Romans was stronger than the concrete made today. For example, saltwater erodes modern concrete within a matter of years, but some of the sea walls built by the Romans 2,000 years ago still remain intact.**

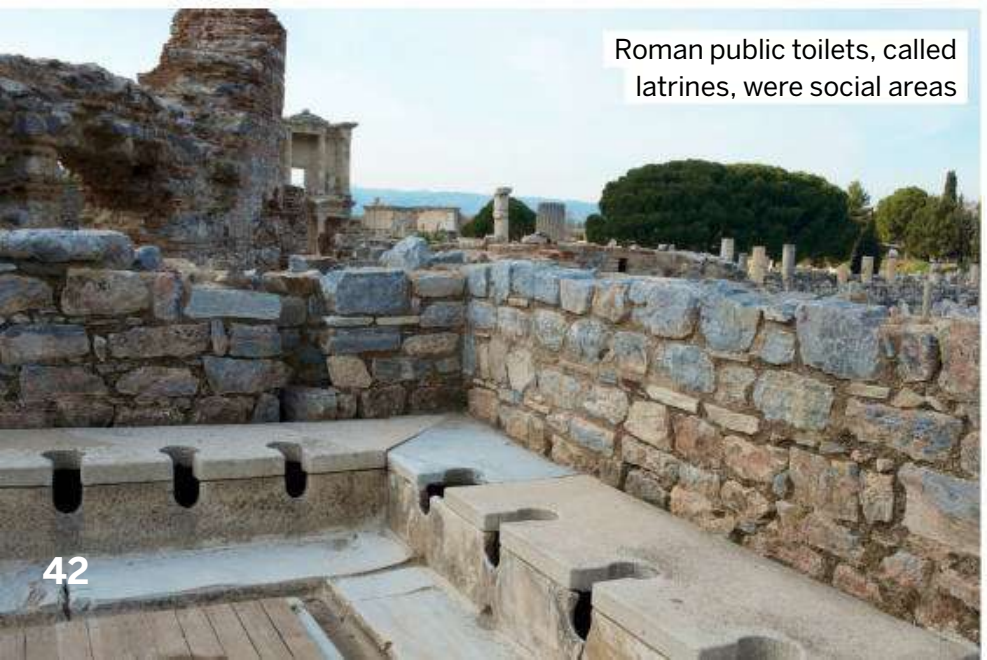
**To uncover the Romans' construction secret, scientists studied the mineral components of ancient maritime concrete. They found that a mixture of lime and volcanic rock was used. This created a mortar and volcanic tuff. To add further strength, the mortar was placed in seawater. Water molecules hydrated the lime, which underwent a chemical reaction with the ash, cementing them together. This formed a strong calcium-aluminium-silicate-hydrate. Even structures that weren't underwater were hardy – using volcanic rock and ash to build the Colosseum has kept this famous wonder relatively intact for centuries.**

The Colosseum amphitheatre is made from stone, concrete and tuff

### Did you know?

**Many medical breakthroughs were made on the battlefield**



Roman public toilets, called latrines, were social areas

The surface structure of some Roman roads can still be seen today

## HOW TO BIND BOOKS

**Although the Romans were far from the first to leave written records, they're credited with creating the first form of 'books'. Called codices, bound wax tablets were used instead of today's paper. The wax was engraved with a sharp instrument called a stylus. These documents transformed literacy, as binding tablets could fold together and were thinner than the large clay tablets they originally wrote on. Codices were also easier to handle than scrolls. Later on, the wax tablets were replaced by lighter animal skins.**

A reproduction of a bound wax tablet

## 5 SURGICAL INVENTIONS

**THESE ARE STILL IN USE TODAY**

**1 BONE DRILLS**
The Romans used bone drills to remove diseased bone. These were similar in appearance to today's corkscrews.

**2 FORCEPS**
This was one of the most common surgical tools in Roman times. Forceps were used to remove small bone fragments.

**3 CAESAREAN SECTIONS**
It was a written law in ancient Roman times that if a woman died while giving birth, the child had to be cut out of her body. This led to the first C-sections.

**4 ANTISEPTIC SURGERY**
Not only did the Romans invent many useful medical tools, they also learned how to keep them clean. They washed utensils in hot water as an early method to kill disease-causing microorganisms.

**5 SYRINGES**
In ancient Roman literature there are records of some of the earliest uses of syringes. These were used to apply medical ointments.

© Alamy / Getty / Illustration by Nicholas Forder / Wiki: Peter van der Sluijs / Wiki: Wellcome Collection Gallery

# PYTHAGORAS OF SAMOS

## This ancient Greek polymath's life is shrouded in mystery

WORDS **JO ELPHICK**

Born in Samos, Greece, around 570 BCE, Pythagoras is said to be the first pure mathematician who claimed everything is a number. Although he's most famous for his mathematical theorem, he also made extraordinary developments in astronomy, geometry and the theory of music. He founded a philosophical and religious school in Crotone, Italy, where he taught that the whole cosmos is a scale and a number.

While playing his lyre, an ancient Greek stringed instrument, he discovered that the vibrating strings created a beautiful sound when the ratios of the lengths of the wires were whole numbers, and that this was also true of other instruments. He combined numbers with his understanding of the planets, and this resulted in him believing that when the planets were in harmony, it created beautiful music humans were incapable of hearing. He concluded that mathematics and music were interconnected and that knowledge of one area led to an understanding of the other. He also believed that music had healing properties, and would often play his lyre for the sick and dying.

Little is known about the life of Pythagoras, and as a result many bizarre myths have sprung up around him. It's been claimed that he took part in the Olympics and was awarded laurels for pugilism, or boxing, when he was a young man. It was also said that he fought in the Trojan Wars in a previous life. This last myth reflects Pythagoras' belief in metempsychosis, which argues that all souls are everlasting – when the physical body dies, the soul simply floats away and finds a new body to live in. Reports stated he had been able to clearly recall four previous lives. His fascination with astronomy led him to confirm that Earth was in fact a sphere, and through patient study he discovered that the 'evening star' and the 'morning star' were the same planet: Venus.

Although Pythagoras' theorem is still taught in classrooms today, no one would recognise his original school of thought, as it combined his mathematical teachings with philosophy and religion. His followers, the Pythagoreans, created a secret commune, filled with strange rules and regulations.

Far from being the master mathematician we think of today, Pythagoras was known for his belief in reincarnation, religious rituals and almost magical abilities. For example, it was said that he could be in two places at the same time. Today these mystical elements have been almost forgotten, and he is now looked upon as a founding father of science and mathematics.

**Above:** Pythagoras, a pioneer of early Greek philosophy, mathematics and natural science

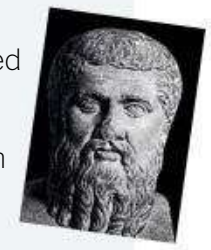
**Opposite:** Pythagoras drawing his theorem in the sand

**Opposite, top left:** A woodcut engraving of Pythagoras, published in 1881

**Opposite, top right:** Pythagoras was the first to discover that the morning star and evening star were both the planet Venus

## IN THEIR FOOTSTEPS

**1 PLATO**

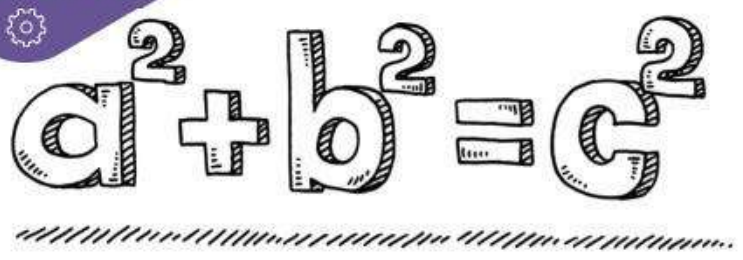


Plato created the world's first university in Athens. Although different from a modern university, his academy was a place where people could meet and share academic beliefs. Plato based a large proportion of his teachings on the thoughts of Pythagoras and his Pythagorean disciples. Bertrand Russell claimed that Pythagoras should be considered "the most influential philosopher of all time".

**2 ARISTOTLE**

Aristotle was also interested in the concept of a soul. He wrote *On the Soul*, which set out to examine the psychology of humankind, the principles of which are still referred to by psychologists today. He combined metaphysics with scientific investigation, just as Pythagoras had achieved with metaphysics and number theory. He was also inspired by Pythagoras' interest in astronomy, developing the physical model of the heavens.

## The BIG idea

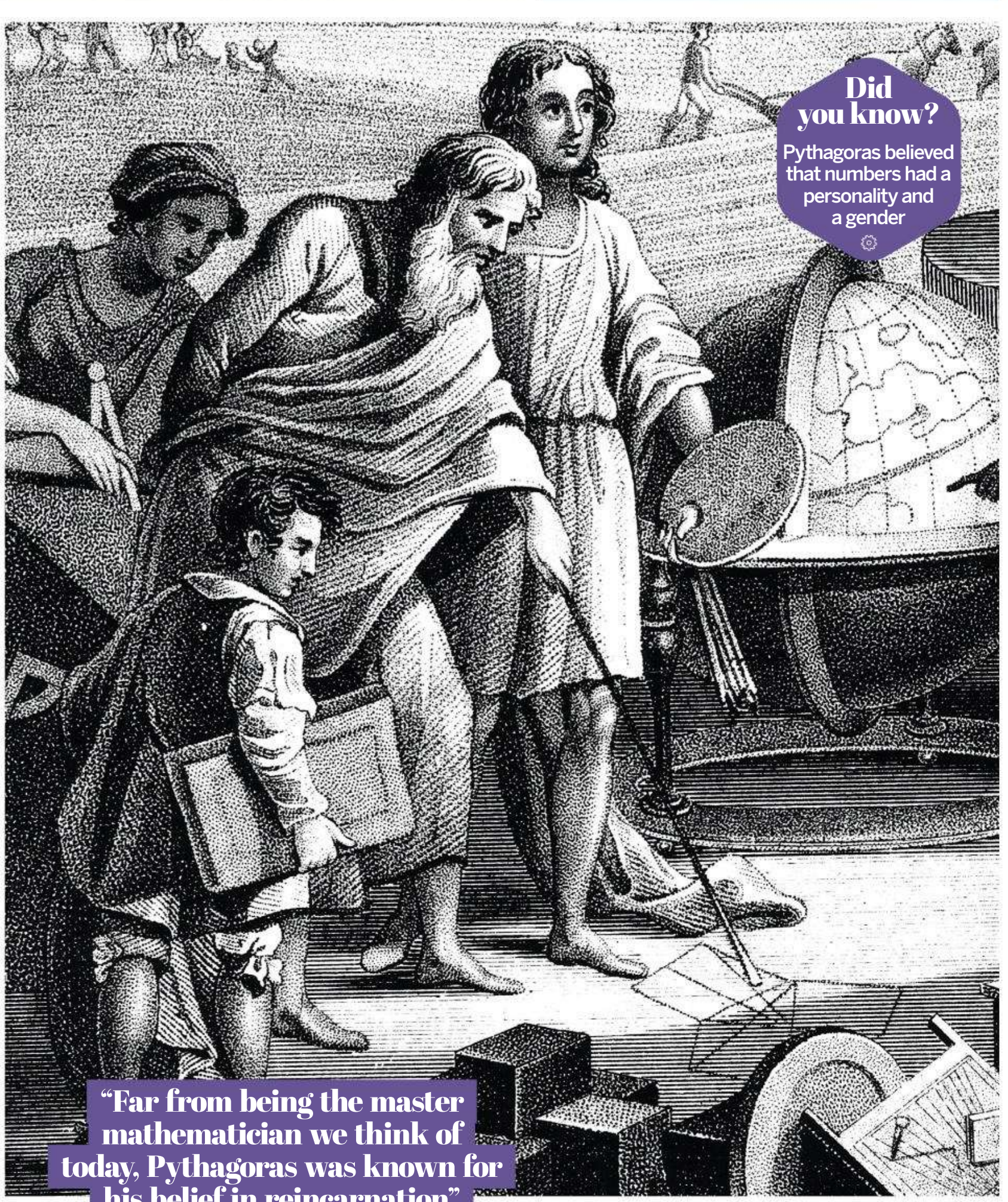



Many children learn this world-famous equation at some point during their school life

### CHILDREN ARE STILL TAUGHT PYTHAGORAS' THEOREM TODAY

**This states that in a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides. In other words, when a triangle has a right angle and squares are found of each of the three sides, then the biggest square has the same area as the other two squares combined. The equation can be used to work out the length of a third side if only two measurements are given.**

**DID YOU KNOW?** The name 'Pythagoras' means 'he who was announced by the Oracle' and relates to the god Apollo



**Did you know?**

Pythagoras believed that numbers had a personality and a gender

"Far from being the master mathematician we think of today, Pythagoras was known for his belief in reincarnation"

## A LIFE'S WORK

**Pythagoras' life is shrouded in mystery, and dates are estimations**

### 570 BCE
Pythagoras was born on the Greek Island of Samos.

### 552 BCE
At the age of 18 he may have participated in the Olympic Games.

### 540 BCE
He travelled to Egypt, meeting the temple priests, who agreed to teach him all they knew.

### 532 BCE
He emigrated to Italy and established his school and Pythagorean Brotherhood.

### 525 BCE
Pythagoras was taken prisoner by Cambyses II, king of Persia, and sent to Babylon.

### 520 BCE
He escaped from Babylon and made his way back to Samos before settling in Metapontum.

### 500 BCE
Pythagoras proved his theorem for the first time. The first demonstration was given one year later.

### 499 BCE
Due to political involvement, an uprising occurred against all Pythagoreans.

### 495 BCE
Pythagoras died, possibly during a riot. Others claim he starved himself to death.

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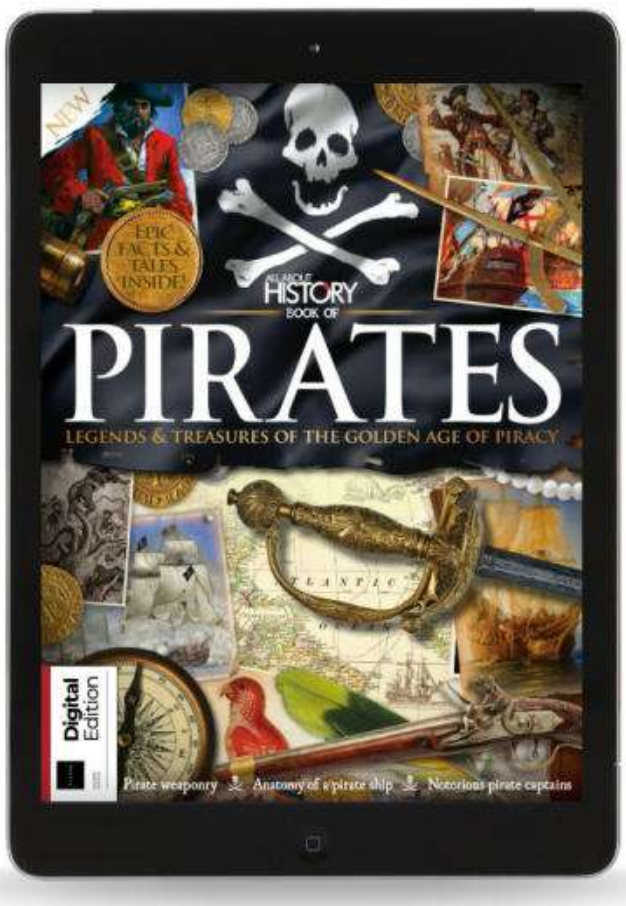


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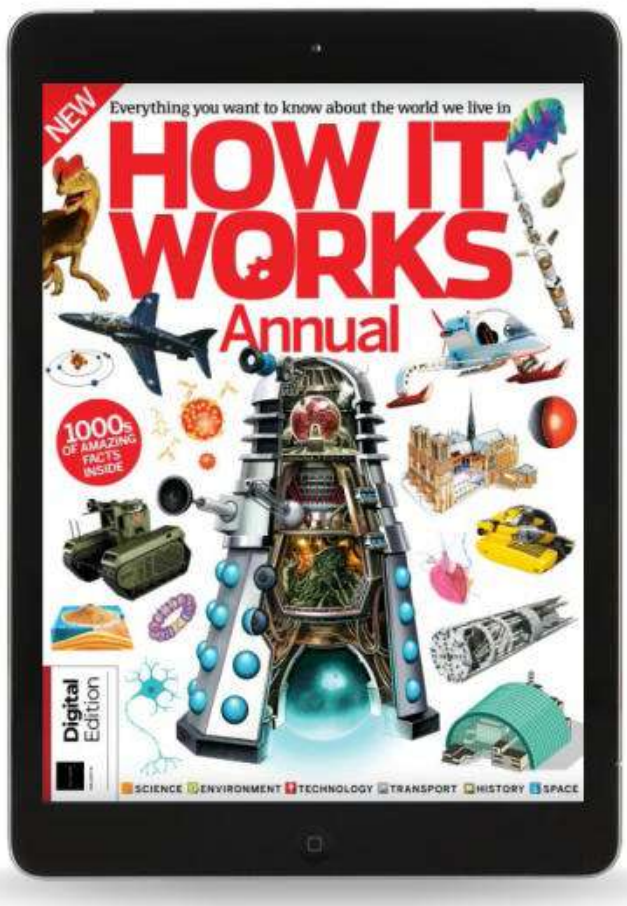


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# 15 OF THE BIGGEST BIRDS ON EARTH

## Explore the fascinating lives of our planet's feathered giants

WORDS SCOTT DUTFIELD

There are almost 10,000 species of birds on Earth, and they come in all sorts of different shapes and sizes – from the tiny bee hummingbird to the massive ostrich. Here we take a look at some of the biggest birds that inhabit our planet, including the tallest, heaviest and those with the widest wingspan.

### HARPY EAGLE

*Harpia harpyja*

Named after a human-bird hybrid in ancient Greek mythology, harpy eagles are some of the biggest birds on Earth. They are among the largest species of eagles, particularly when comparing their weights. An adult female can weigh up to nine kilograms, and males grow up to 15.4 kilograms. To compare, a bald eagle can weigh up to 16 kilograms. These birds soar across South America, kept aloft by their impressive two-metre wingspan, hunting for prey that includes porcupines, deer and opossums. When they have their target in sight, harpy eagles descend at speeds of 50 miles per hour and use their 13-centimetre talons to deliver a fatal blow.

A harpy eagle in the tropical lowland forests of southeastern Mexico

**DID YOU KNOW?** A Laysan albatross was recorded living to 68 years old

Albatrosses flying over snowy mountains in Antarctica

## WANDERING ALBATROSS

*Diomedea exulans*

**Meet the biggest bird in the world – at least in terms of its wingspan. These giant sea birds glide over the ocean with a wingspan up to 3.35 metres wide. Wings of this immense size mean that these albatrosses can spend large amounts of time in the air; for example, one bird was recorded to have wandered around 3,700 miles in only 12 days. There are 23 species of albatross, but unfortunately all but one are either threatened or vulnerable to extinction. This is due to the birds getting caught in hooks and nets while scavenging fish and squid bait from fishing vessels and trawlers.**

A rhea walking through a field

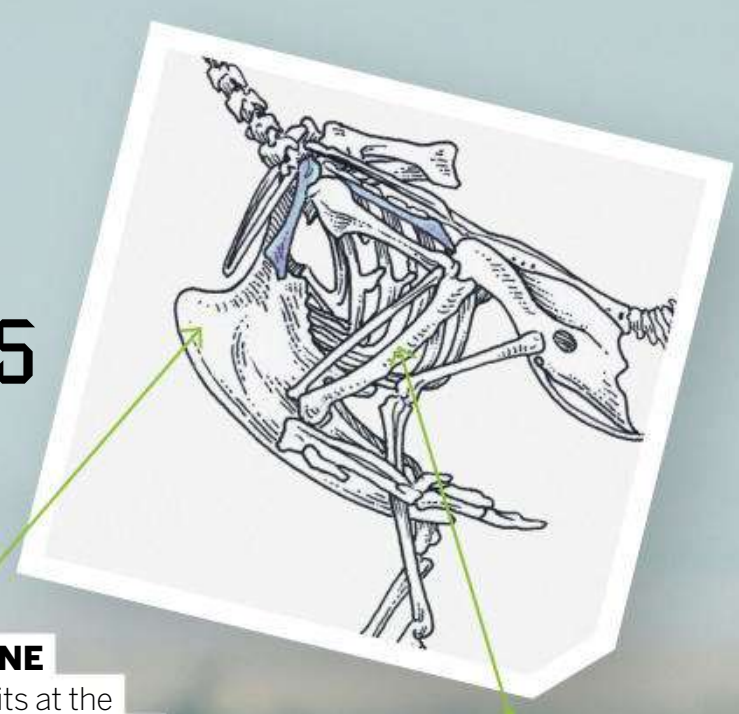
## GREATER RHEA

*Rhea americana*

**Although these birds might look like juvenile ostriches, rhea are actually their South American cousins. At only around one-fifth the size of an adult ostrich, rhea can still weigh an impressive 30 kilograms and grow up to 1.5 metres tall. Rhea are flightless birds, and like ostriches they use their wings as balance aids while running at high speeds of up to 40 miles per hour. Female rhea lay up to 40 eggs per breeding season, but it's the males that will incubate the eggs for around 30 days before they hatch.**

# THE FLIGHTLESS WING

**Why ostriches can't fly**



**KEEL BONE**
The keel bone sits at the mid-chest of the ostrich and is less pronounced than in birds that can fly. For those that can fly, the keel is the anchor for muscles used in flight.

**DENSE STRUCTURE**
Unlike flying birds', ostrich bones are not light and hollow. Instead they are more dense and similar to human bones, encasing a tube of marrow.

**Did you know?**
A female ostrich lays up to 18 eggs a year

**HEAVY LIFTING**
Ostriches are far too heavy for their small wings to generate enough lift to get them off the ground.

**FLUFFY FEATHERS**
Unlike the durable feathers of flying birds, ostriches have soft downy feathers, better suited to retaining heat than flying.

A male ostrich in Serengeti National Park, Tanzania

## COMMON OSTRICH

*Struthio camelus*

The biggest of all birds on Earth in both size and weight is undoubtedly the ostrich. These behemoth birds grow up to 2.7 metres tall and can weigh up to 130 kilograms. Despite having a wingspan of up to two metres, ostriches are unable to fly. Instead they use their wings in a similar way to how a ship uses its sails. During a fierce 43 mile per hour run, these birds open out their wings and use them as air rudders for rapid braking and steering. This agility allows them to escape some of the many threats they face on the African savanna, including predatory species such as lions and jackals. In some situations, ostriches will go on the offensive, using their powerful clawed feet to deliver a blow strong enough to kill a lion.

© Getty

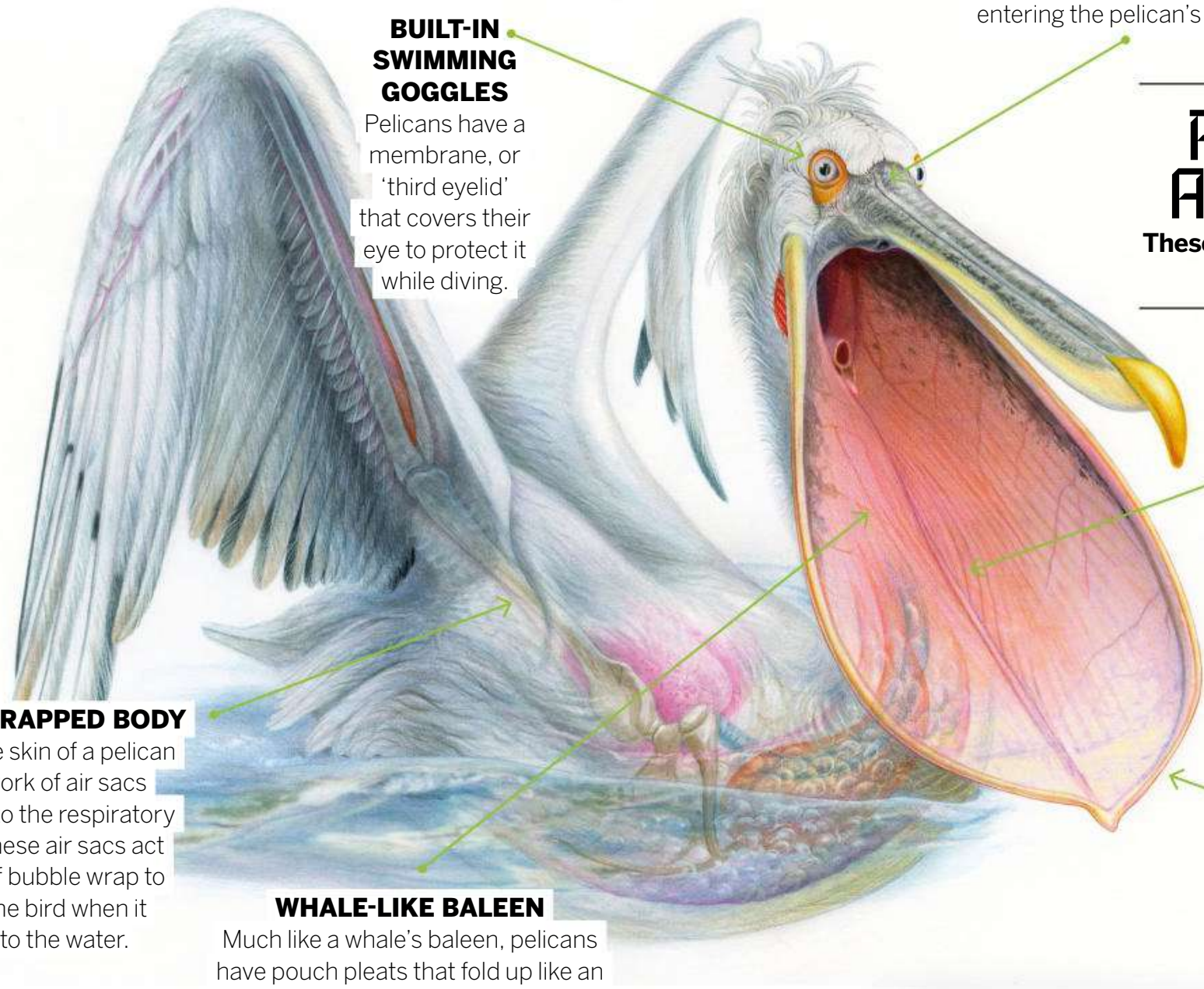
# DALMATIAN PELICAN *Pelecanus crispus*

The Dalmatian pelican is not only the largest species of pelican but is one of the biggest flying birds in the world. With a wingspan of around three metres, these pelicans are high flyers and have been observed to reach altitudes of more than 3,000 metres. Along with a large pair of wings, Dalmatian pelicans have a big appetite. An adult pelican can devour around 1.8 kilograms of fish in a single day. Dalmatian pelicans gather fish by using their enormous bill pouches to dive into the water and scoop prey from near the surface. Once fish are trapped inside their bills, the pelicans will lean their heads forward to strain out the water and devour their meal.

A Dalmatian pelican flying over Lake Kerkini, Greece

## PELICAN ANATOMY

**These seabirds are built to be nature's fishermen**



**BLOCKED NOSTRILS**
Patches of skin prevent water from entering the pelican's nostrils while underwater.

**BUILT-IN SWIMMING GOGGLES**
Pelicans have a membrane, or 'third eyelid' that covers their eye to protect it while diving.

**FISHING POUCH**
This part of the mouth acts as a fishing net. Multiple bones and connective tissue in the pouch allow it to expand when filled with water and fish.

**BUBBLE-WRAPPED BODY**
Beneath the skin of a pelican is a network of air sacs connected to the respiratory system. These air sacs act as a kind of bubble wrap to protect the bird when it dives into the water.

**LOWER JAW**
The lower jaw of the pelican acts as support for the bird's large skin pouch.

**WHALE-LIKE BALEEN**
Much like a whale's baleen, pelicans have pouch pleats that fold up like an accordion when the pouch is empty and expand when the pouch is full.

# SOUTHERN CASSOWARY *Casuarius casuarius*

The southern cassowary is one of the most prehistoric-looking birds, found prowling through New Guinea and mainland Australia. Towering up to two metres, cassowaries are one of the tallest birds. Topping off their height is a prominent helmet called a casque, made of a thick layer of keratin – the same material that makes up your nails and hair. Cassowaries use these helmets to push past vegetation as they run through the forest. As well as being one of the biggest bird species, they've also gained the reputation of being one of the most dangerous. As one of the few birds recorded to have killed humans, cassowaries use their sharp three-toed feet – sporting a middle ten-centimetre long toe – to deliver a fatal swipe to their target.

A southern cassowary from Queensland, Australia

**DID YOU KNOW?** The UK's Bewick's swans travel 4,000 miles from Russia each year during winter

A pair of great bustards in Wiltshire, England

## GREAT BUSTARD
*Otis tarda*

**Great bustards are the largest land birds in Europe, but are also found in Central Asia, Russia and Morocco. Males can weigh up to 14 kilograms and stand almost 1.2 meters tall, which means they're an easy target for hunters. Their numbers are in decline, with over 30 per cent of the global population lost since the 1960s, and they've even become nationally extinct in some countries, such as the UK. The last great bustard in the UK was shot in 1832; the bird was reintroduced in 2004 and currently has a self-sustaining population of more than 100 birds.**

A colony of emperor penguins and their chicks on Snow Hill Island, Antarctica

## EMPEROR PENGUIN
*Aptenodytes forsteri*

**Of the 18 species of penguins on Earth, emperor penguins are the biggest. They stand around 1.2 metres tall and weigh 40 kilograms, but this weight fluctuates regularly throughout the year. These flightless birds utilise their fat stores to insulate themselves against the harsh conditions of Antarctic winter along with several layers of scale-like feathers, which can withstand gusts of up to 68 miles per hour before they're ruffled and the wind cuts through the warm layer. Emperor penguins also huddle together in colonies to cut down heat loss by 50 per cent.**

**Did you know?**

**An Emu can run at speeds of up to 30 miles per hour**

Shoebills were once classified as storks

## SHOEBILL *Balaeniceps rex*

Also known as whale-headed storks, shoebills are one of Africa's strangest and tallest birds. These unusual creatures stand at around 1.5 meters tall and spend their time wading among freshwater swamps and marshes, hunting fish and other small aquatic species. As hunters, shoebills have a high success rate, delivering a fatal strike into the water around 60 per cent of the time. These solitary birds are not found in flocks and often occupy a territory of just over a square mile.

An Andean condor flying over Colca Canyon in southern Peru

## ANDEAN CONDOR
*Vultur gryphus*

This is the largest species of raptor on the planet. They have the second-largest wingspan of any bird, at around 3.2 metres. Along with their impressive wingspan, Andean condors can ascend to heights of up to 5,500 metres, passing over the peaks of the Andes. Due to their large wingspan, these birds can glide on air currents with ease without expelling much energy. Andean condors are a species of vulture, and like many vulture species they scavenge much of their diet from dying or deceased animals, chomping down around 6.8 kilograms of carrion (dead or decaying flesh) in a single meal. The Andean condor has a long life span of around 50 years in the wild and up to 80 years in captivity.

## 5 OF THE UK'S BIGGEST BIRDS

**1 CAPERCAILLIE**
*TETRAO UROGALLUS*

Capercaillies are massive woodland grouse that live in Scottish pinewoods. These birds grow up to five kilograms in weight and have a wingspan of around 125 centimetres.

**2 MUTE SWAN**
*CYGNUS OLOR*

Weighing up to 12 kilograms, mute swans are the heaviest birds in Britain. These birds also have an impressive wingspan of up to 2.3 metres.

**3 COMMON CRANE**
*GRUS GRUS*

These 1.2-metre-tall birds can be found through wetlands in Norfolk. However, their populations have been rapidly declining, with only 48 breeding pairs in the UK.

**4 WHITE-TAILED EAGLE**
*HALIAEETUS ALBICILLA*

This eagle has a massive wingspan up to 2.4 metres wide. Thought to be extinct in the UK during the early 20th century, it's estimated that there are now 150 breeding pairs.

**5 GREY HERON**
*ARDEA CINEREA*

Standing almost a metre in height, herons are one of the UK's tallest birds. These grey giants spend their time fishing in wetlands, but have also been known to eat other small birds and mammals.

© Getty / Illustration by The Art Agency: Sandra Doyle

# HOW DO FISH BREATHE?

## Discover how aquatic animals use their gills to breathe underwater

WORDS **ANDY EXTANCE**

Whale sharks have five large gill slits on each side of their heads

Goldfish don't look much like gorillas, but the way these creatures breathe has something in common. They both need the gas we call oxygen to survive. Oxygen helps release the energy that powers our bodies from the sugary chemical glucose in a process called respiration. Respiration releases another gas, carbon dioxide, which gorillas, humans and fish breathe out. Gorillas can suck oxygen from the air through their mouths down into their lungs to breathe easily. Goldfish have it harder.

**Did you know?**

**Tiny ectoparasites can live inside fish gills**

To breathe, fish have to pull out the molecules of oxygen dissolved in water using their gills. The amount of oxygen in the air is a lot higher than the amount of oxygen in water, though. That means that fish have a much more difficult time breathing than gorillas and humans do. Fish take water into their mouths just like we take in air, opening and closing their lips. This water then filters through the gills, organs that have lots of feathery filaments made of protein molecules.

The filaments look like tiny bristles on a brush. They have thousands of tiny blood vessels to help oxygen get into the bloodstream – even more blood vessels than in human lungs. The larger number of blood vessels in fish gives a much larger surface for oxygen to pass across. That helps them pull the dissolved oxygen from the water around them and release carbon dioxide back into it.

The difference in design between lungs and gills is the main reason why people – and gorillas – can't breathe underwater. Gills are much better at pulling oxygen from water than lungs. Fish extract over four-fifths of the oxygen available in water. Fish also use less energy to live than mammals like humans and gorillas, so need less oxygen. They do need at least some oxygen though. That means that water with low oxygen levels is just as deadly for fish as low oxygen in the air can be for us. Anoxic and hypoxic zones, sometimes called dead zones, are areas of the ocean where oxygen is so scarce that fish cannot survive.

If breathing underwater is such hard work, why don't fish just breathe air like we do? Gills need water to maintain their structure and prevent their thin tissues from collapsing. Just like humans drown underwater, fish can drown in air. If their gills are exposed to the open air for too long, they can collapse, causing the fish to suffocate. They are especially suited for life underwater, just as we are for life on land.

The axolotl is an aquatic amphibian with gills sticking out of its head

### FISH THAT CAN BREATHE AIR

**Labyrinth fish are named after their lung-like labyrinth organs, which have many maze-like compartments known as lamellae. Those labyrinth organs help some fish species, including bettas, gouramis and paradise fish, to breathe air just like humans do. They also have gills so they can breathe oxygen dissolved in water.**

**For millions of years, these fish and their ancestors have lived in very low-oxygen waters. Evolution has favoured any fish that are born with advantages that help them make the most of the oxygen they can find.**

**If the water labyrinth fishes live in runs out of oxygen, they can dash up to the surface and use their labyrinth organs for a gulp of air. They can even survive for hours outside of the water. Many labyrinth fish also build bubble nests. Males can blow bubbles to create elaborate nests of air at the surface of the water.**

*Betta splendens*, or Siamese fighting fish, have labyrinth organs to breathe air

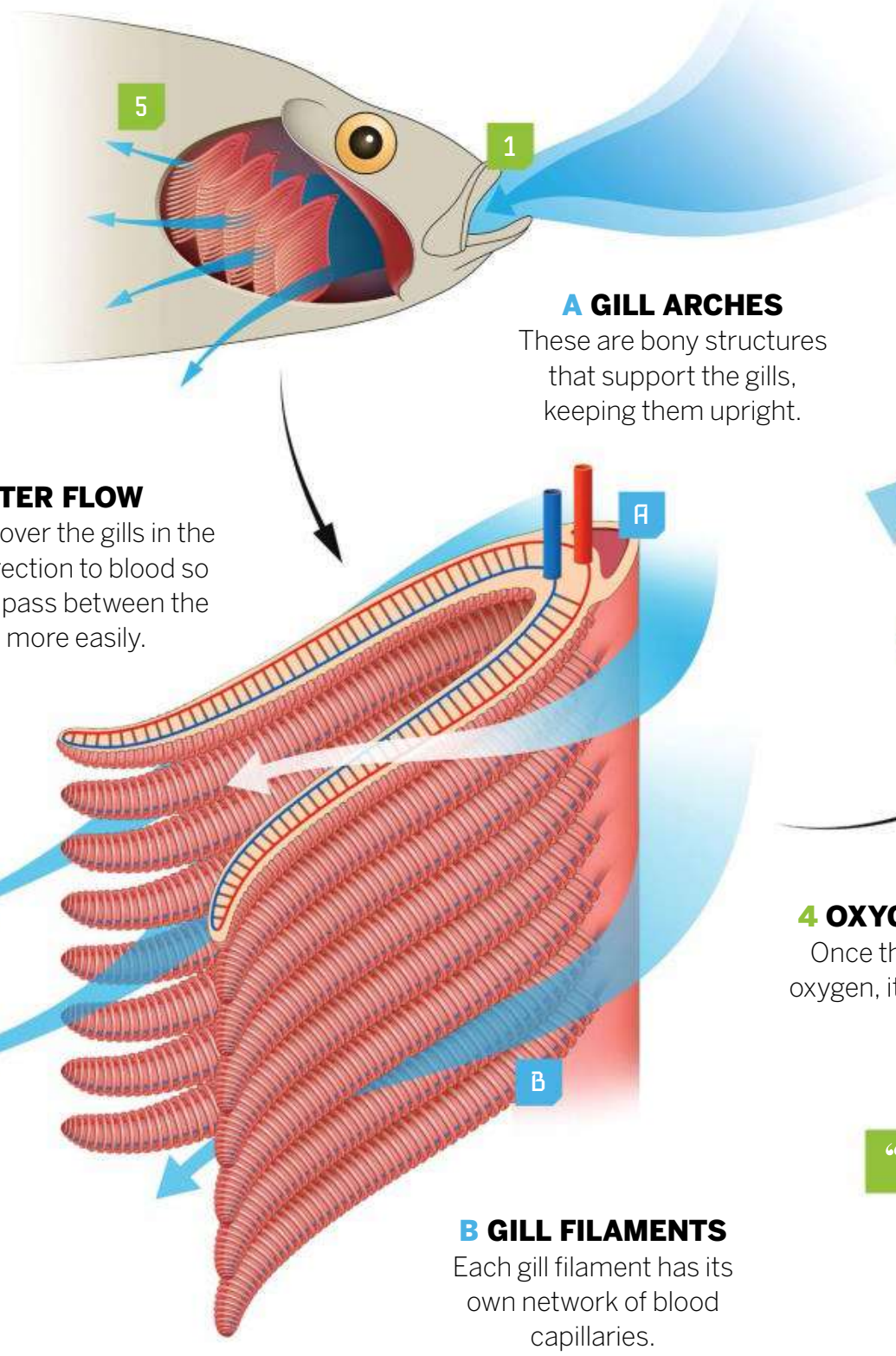
**DID YOU KNOW?** Crabs, aquatic snails and lobsters all use gills to breathe

# EXPLORING GILLS

**Fish gills are intricate organs, especially suited for efficient gas exchange**

Some aquatic animals, like dolphins and whales, get their air using lungs like we do

**5 OPERCULUM**
Water leaves the gills through the operculum.

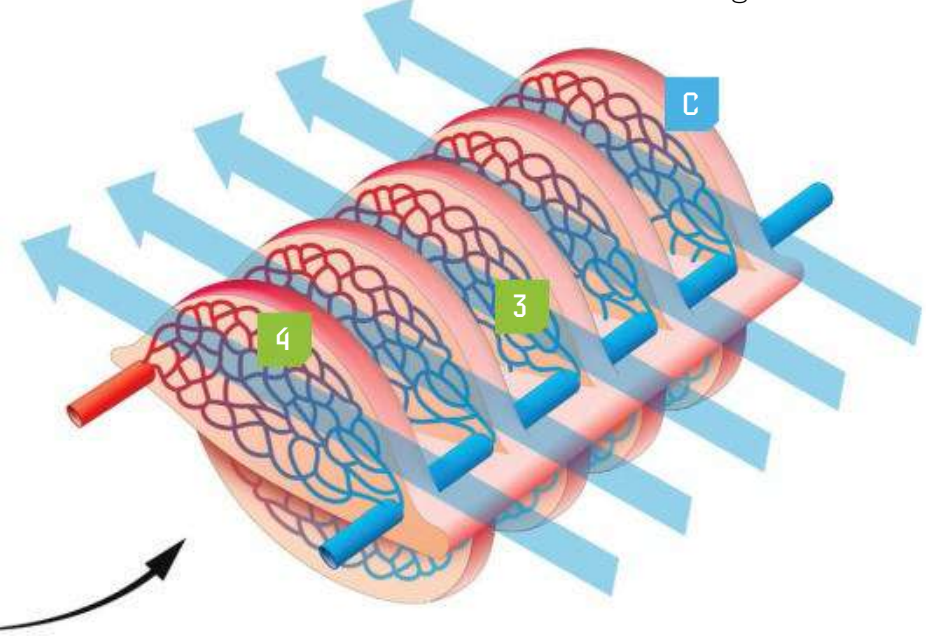



**1 BUCCAL CAVITY**
Water enters through the fish's mouth, also known as the buccal cavity.

**C CAPILLARY NETWORK**
Thousands of blood vessels make up each capillary network in the gill filaments.

**A GILL ARCHES**
These are bony structures that support the gills, keeping them upright.

**2 WATER FLOW**
Water flows over the gills in the opposite direction to blood so oxygen can pass between the liquids more easily.




**4 OXYGENATED BLOOD**
Once the blood has gained oxygen, it delivers it to the rest of the body.

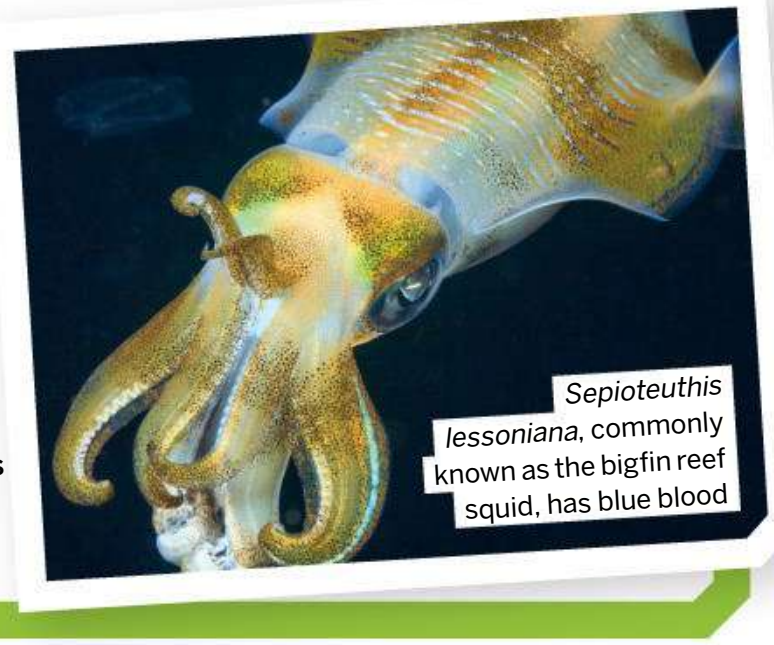
**3 DEOXYGENATED BLOOD**
Blood without oxygen from the body enters the gill filaments to pick up oxygen.

**B GILL FILAMENTS**
Each gill filament has its own network of blood capillaries.

**"Fish extract over four-fifths of the oxygen available in water"**

## BLUE-BLOODED CREATURES

**If you cut most animals, blood comes out red. By contrast, many underwater creatures, like crabs and lobsters, octopuses and squid, bleed blue. Our blood is red because of a chemical called haemoglobin in our blood cells. Haemoglobin includes an atom of iron, which clings on to oxygen molecules. Blood cells containing haemoglobin then carry oxygen around our bodies, working like a bright-red delivery van inside our blood vessels. Blue-blooded creatures have a chemical called hemocyanin instead of haemoglobin. It works in a very similar way, using copper instead of iron. The copper atoms turn their blood blue.**



*Sepioteuthis lessoniana*, commonly known as the bigfin reef squid, has blue blood

© Getty / Alamy

# HA LONG BAY EXPLORED

How this stunning Vietnamese bay developed such distinctive geology

WORDS **AILSA HARVEY**

In the Gulf of Tonkin, 101 miles southeast of Hanoi, Vietnam, around 2,000 chalky pillars and islands protrude from the sea. These towering limestone rocks are called karsts, and they've been sculpted into unique shapes by erosion from the rain and sea. Most of them are between 50 and 100 metres tall. The geological evolution that led to this seascape was a 500-million-year process, with the limestone beginning to form about 300 million years ago.

Ha Long Bay's formations are at least 3 million years old, yet the area has only been inhabited for tens of thousands of years. While the green-topped limestone towers and islands are home to a variety of plant and animal life, the majority are unsuitable for human settlement. Ha Long Bay's population of 1,600 mainly live in four floating fishing villages: Cua Van, Ba Hang, Cong Tau and Vung Vieng.

Not only does Ha Long Bay have a stunning otherworldly appearance, but its rock formations, largely unaltered by humans, provide information for one of the world's biggest databases of karst formation. Within the bay there's a great range of limestone structures, revealing how the landscape changed across major stages of Earth's history.

**Did you know?**

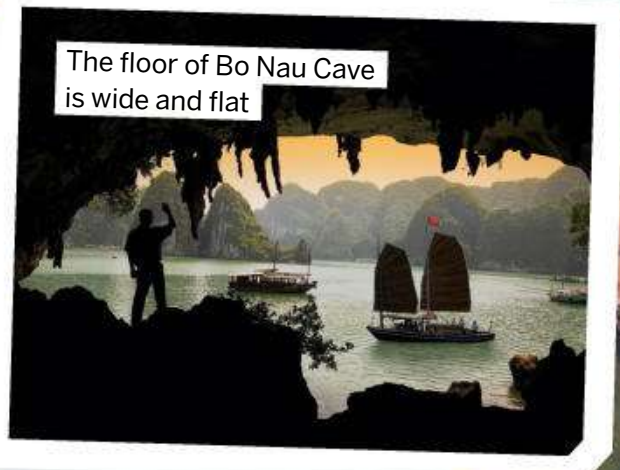
Ha Long Bay had 4.4 million visitors in 2019

The islands and rock formations vary widely in size

## COMPLEX CAVES

**As the rock here is divided into thousands of islands surrounded by seawater, a large surface area of limestone is exposed to the elements. The sea is constantly eroding the islands and land of Ha Long Bay, and as a result there's an abundance of passages and caves. 30 of these caves are currently accessible to people. Ha Long Bay's cave types include phreatic caves and marine notch caves. The oldest caves in the bay are the phreatic caves, which formed by carbonic acid from groundwater dissolving the limestone. This created weaknesses in the rock, allowing water to flow in under pressure and creating the gaps in the rock.**

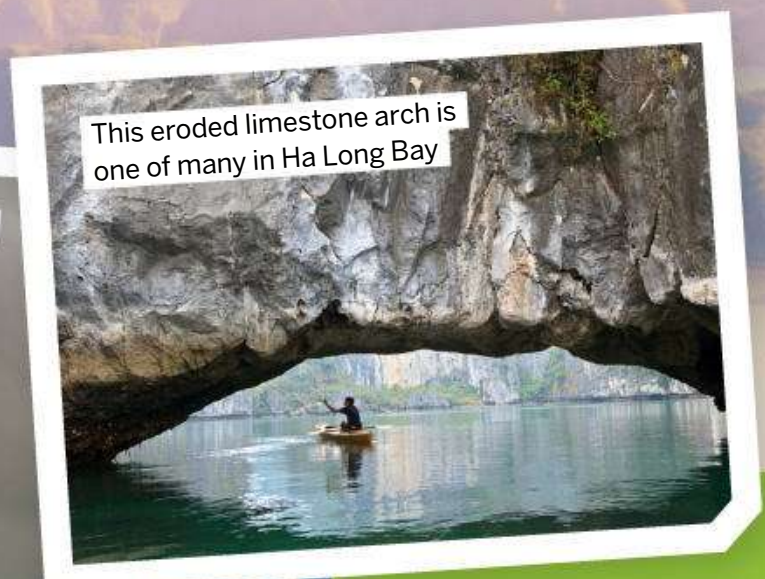
**Notch caves grow over time at the surface of the sea. As waves continue to crash into the limestone, pieces are eroded and washed out to sea. This process is called abrasion and leaves an indent in the rock at the height of the waves.**



The floor of Bo Nau Cave is wide and flat

**DID YOU KNOW?** Some of the animals that live on Ha Long Bay's islands include monkeys, lizards and antelopes

Ngon Tay Islet is also called Finger Islet


This eroded limestone arch is one of many in Ha Long Bay

# HOW THE LIMESTONE PILLARS WERE MADE

**1 LIMESTONE LANDSCAPE**
340 million years ago, during the Carboniferous Period, the limestone of Ha Long Bay began to form.

**2 ENTERING THE OCEAN**
As the climate was warmer and wetter, much of the carbonate sediment was washed into the ocean.

**3 HARDENING ROCK**
In the sea, the limestone gradually hardened, growing to thicknesses of up to 1,200 metres over millions of years.

**4 BECOMING ISLANDS**
The movement of tectonic plates eventually brought the limestone above sea level.

**5 ERODING SEASCAPE**
Coastal erosion worked on the rock, carving it into the tall karsts that exist in the bay today.

© Alamy / Getty

# SECRETS OF DIAMONDS

**What are these sparkling, harder-than-rock gems? Where do they come from and why are they so special?**

WORDS **ANDREW MAY**

**DID YOU KNOW?** The ancient Greeks believed that diamonds were splinters of stars that had fallen to Earth

Diamonds are the most sought-after and admired gemstones, with a sparkling brilliance that sets them apart from other gems. That's as true today, with diamonds mined on an industrial scale, as it was thousands of years ago when they were much rarer. As Roman historian Pliny wrote in the 1st century CE: "Diamond is the most valuable, not only of precious stones, but of all things in this world."

The gems were first discovered around 2,500 years ago in India, where they were prized as divine objects. These diamonds weren't mined in the modern sense – they were simply collected from the sediment in rivers and streams. Their striking appearance made them highly desirable, and by the 4th century BCE they were being traded with other parts of the world. Their extreme rarity meant that only the very wealthiest could afford them, and diamonds became the ultimate status symbol among the medieval elite. It was only in the 19th century, when more extensive diamond deposits were found in South Africa, that they became accessible to the general public.

**Did you know?**

**A perfect, flawless diamond is called a paragon**

Diamond crystals are made from just one chemical element: carbon. The same is true of graphite, a much more common mineral that couldn't be more different in appearance and properties. Graphite is what pencil lead is made from, and it's so soft that it rubs off onto the page when you write with it, leaving its mark. Diamond, on the other hand, is one of the hardest known substances – so hard it can only be scratched with another diamond. The difference lies in the arrangement of carbon atoms. In graphite they form planar sheets, which can easily glide against each other, while in diamond they form a rigid three-dimensional structure. The hardness of diamond means it has other more practical uses besides jewellery, particularly for polishing, cutting and drilling.

While carbon normally exists as graphite on Earth's surface, it can form diamond at much greater depths, where temperatures and pressures are far higher. In a few places on the planet, diamond-bearing material from these depths has been carried up to the surface by volcanic eruptions, and some of this material was subsequently washed into the riverbeds where diamonds were first found. Today, however, most diamonds come from directly mining diamond-bearing rock, which is called kimberlite after the mining town of Kimberley in South Africa where it was first found.

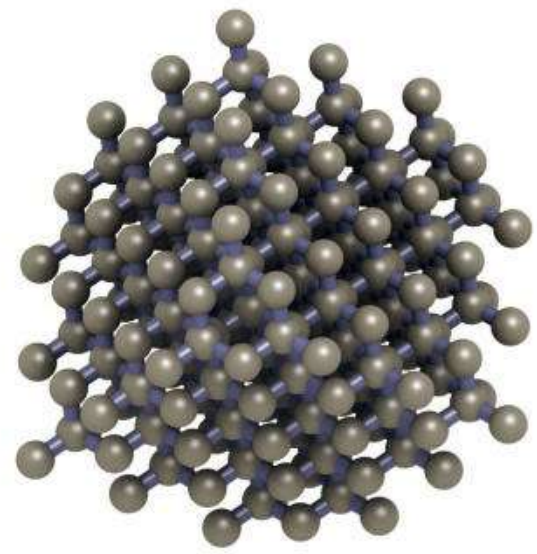
Not all diamonds are the same. Some aren't suitable for use in jewellery and find their way into industrial applications. Even gem-quality diamonds vary considerably, and are typically graded according to the 'four Cs' of cut, colour, clarity and carat. The first three are self-explanatory, while a carat is a measure of weight equivalent to 200 milligrams.

At one time diamonds were expensive purely because of their rarity, but today they're actually less scarce than rubies or emeralds. However, diamond production involves a costly processing chain all the way from mining to polishing. On top of that, there's a huge worldwide demand for diamonds, mostly due to their widespread use in engagement rings – a 'tradition' which originated in a clever marketing campaign in the 1930s.

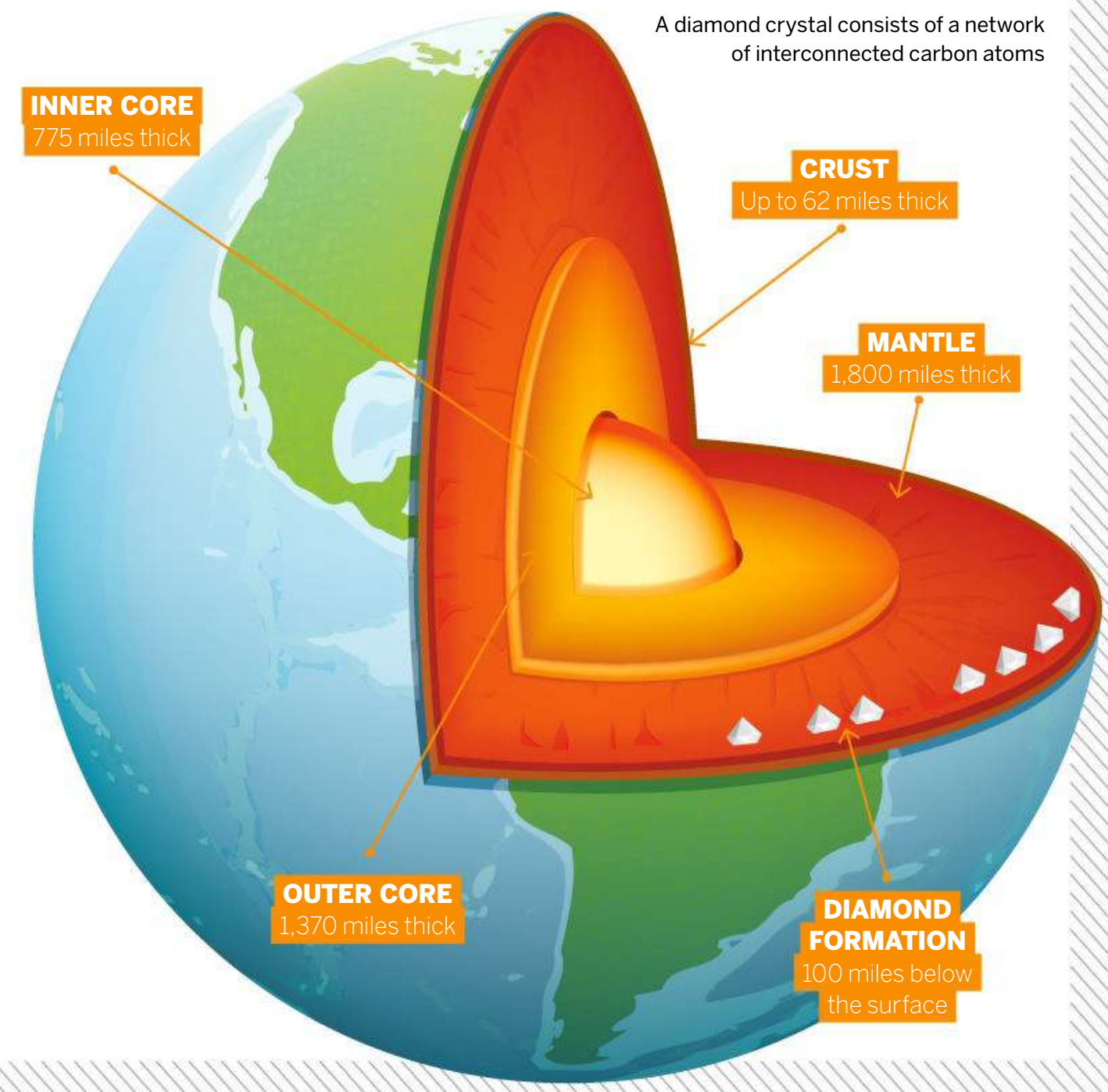
When James Bond creator Ian Fleming released *Diamonds Are Forever* in 1956, he might have been quoting an age-old proverb. But it turns out that this too was a marketing slogan that had been coined less than a decade earlier. And it's not even true, because diamond is an unstable form of carbon that eventually degrades to graphite – although it takes millions of years to do so.

**"The gems were discovered 2,500 years ago in India, prized as divine objects"**

Size doesn't always matter when it comes to diamonds

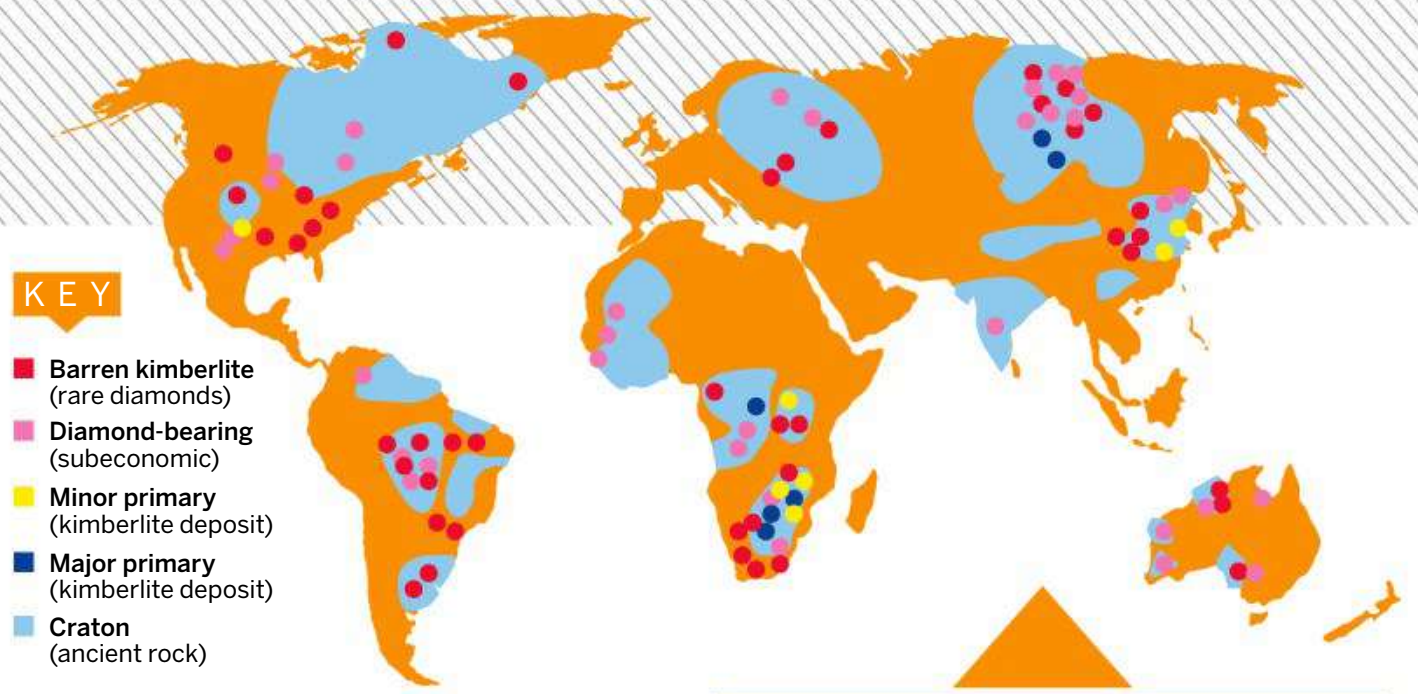


A diamond crystal consists of a network of interconnected carbon atoms




© Getty

# DIAMOND MINING




A diamond is essentially just carbon, one of the most common elements. But we usually find carbon compounded with other elements, and when pure carbon does occur on the Earth's surface it takes the form of graphite. Making diamond requires much higher temperatures and pressures – those which are only found inside the Earth's mantle at depths of a hundred miles or more. There may be lots of diamonds there – perhaps as much as a quadrillion tonnes – but they're totally inaccessible to us.

The only way to get mantle material up to the surface is through a volcanic eruption, and today this simply doesn't happen deep enough to bring up diamonds. But billions of years ago, when the Earth was hotter, such eruptions did occur. They resulted in vertical columns of rock that originated deep in the mantle, and some of these – called kimberlite pipes – contain diamonds.

**Did you know?**

**Blood diamonds are diamonds mined in a war zone**

Where kimberlite is exposed on the surface, it erodes like any other rock, and for centuries the products of this erosion, typically found in riverbeds, were the only source of diamonds. Then, around 1867, a 15-year-old boy named Erasmus Jacobs found a diamond on the bank of the Orange River in South Africa. Subsequent investigations led to the discovery of the first solid outcrops of kimberlite, named after the mining town of Kimberley that grew up around them.

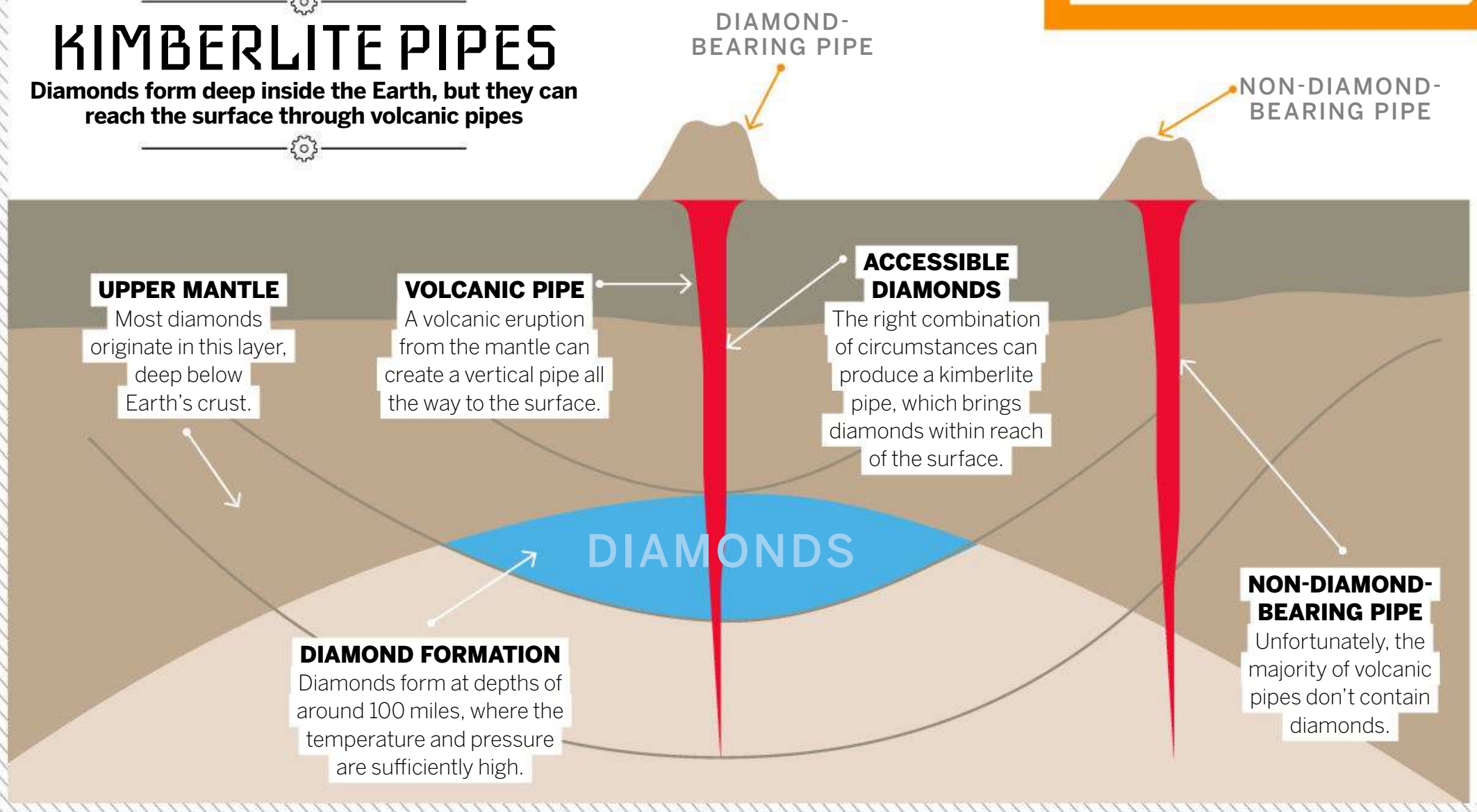
Kimberlite pipes can be mined in two ways: either underground via tunnelling, or in open-pit mines where any overlying layers have been removed. This may sound analogous to coal mining, but whereas coal is solid rock that can be broken up and used almost immediately, diamonds make up only a tiny proportion of kimberlite. Around 250 tonnes of ore needs to be mined to produce a single gem-quality diamond of just one carat, or 200 milligrams.

## WHERE THESE GEMS ARE FOUND

**Historically, the epicentre of diamond mining activity was in Africa, but more recently diamonds have been found in many other parts of the world. Africa still plays a leading role, with countries such as Botswana, Angola, South Africa, Namibia and the Democratic Republic of the Congo all producing more than a million carats of diamonds each year. However, the combined output of those five countries – around 30 million carats – is exceeded by two non-African countries, Russia and Canada, which produce 41 million carats between them. And many other countries produce smaller quantities of gem-quality diamonds, including Australia, Brazil and Guyana.**

## KIMBERLITE PIPES

**Diamonds form deep inside the Earth, but they can reach the surface through volcanic pipes**



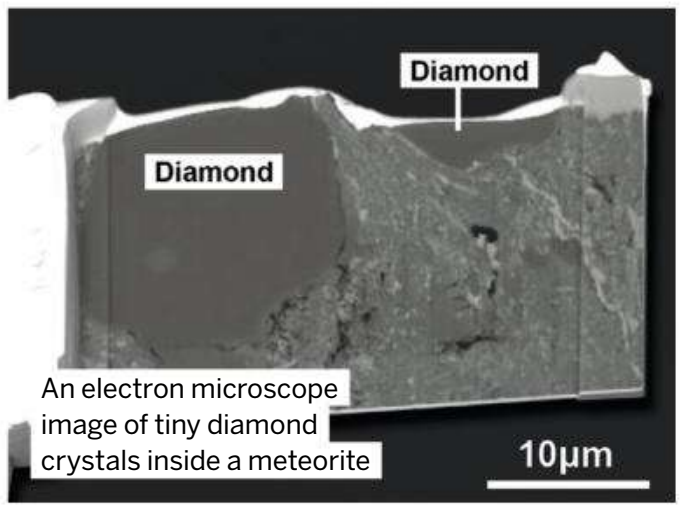
**DID YOU KNOW?** Some white dwarf stars may consist of crystallised carbon, effectively making them Earth-sized diamonds

## SPARKLING SKY

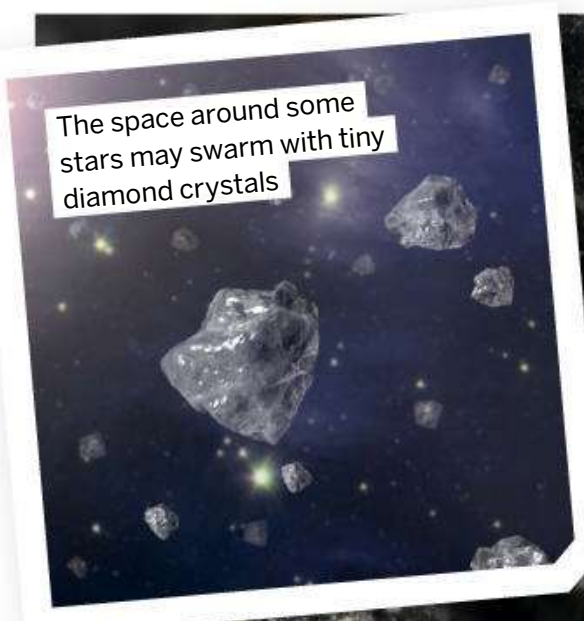
Although we think of diamonds as being very rare, the conditions which produce them occur quite widely throughout the universe. As a result, there really are 'diamonds in the sky'. We have direct evidence of this in the form of diamond-containing meteorites, which originated very early in the history of the Solar System.

Fast-forwarding to the present day, Earth isn't the only planet in the Solar System where diamonds can be found. Deep inside the atmospheres of the ice giants Neptune and Uranus, carbon can be compressed to the extreme pressures and temperatures needed to form diamonds. These then sink down to the planetary cores in the form of a spectacular 'diamond rain'.

Looking beyond the Solar System, it may be possible to find planets with many more diamonds than Earth. It's conjectured that planets orbiting carbon-rich stars would have a much higher diamond content than our own planet. A few years ago there was a flurry of excitement around one particular exoplanet, 55 Cancri e, which was hailed as the 'diamond planet' because it was believed to be especially rich in diamonds. However, while that theory hasn't been completely disproved, it seems much less likely now.



An electron microscope image of tiny diamond crystals inside a meteorite


The space around some stars may swarm with tiny diamond crystals


Rough diamonds, like this one seen in raw kimberlite, are less glamorous than cut ones

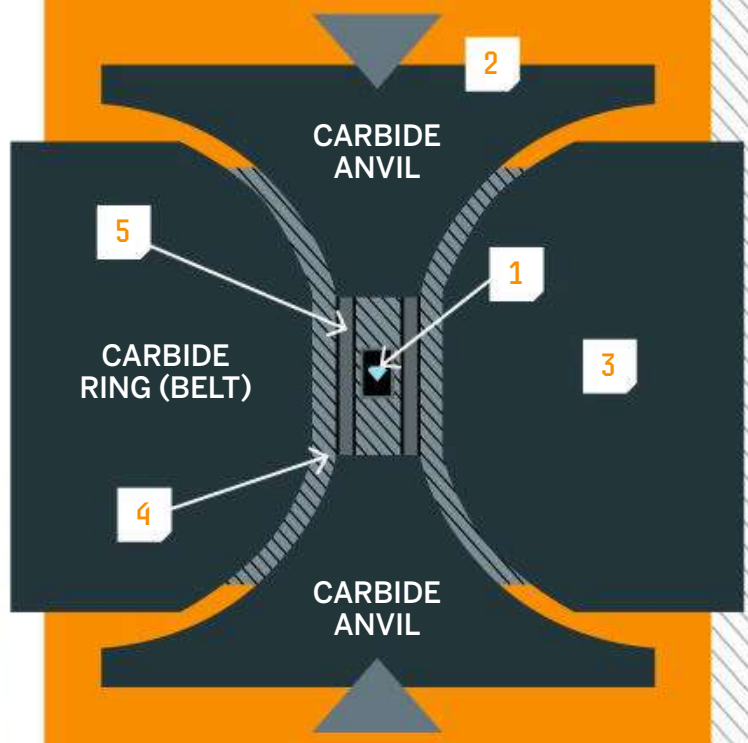
## LAB-GROWN

There's nothing mystical or supernatural about diamonds – they're simply the form that carbon takes under certain conditions of temperature and pressure. Natural diamonds were formed where these conditions exist inside the Earth, but it's also possible to create the necessary conditions artificially. This has been done on a commercial scale to make synthetic diamonds since the 1950s. One approach – called the high-pressure, high-temperature (HPHT) technique – attempts to mimic the natural process as closely as possible. An alternative, called chemical vapour deposition (CVD), requires less extreme temperatures and pressures. At first synthetic diamonds were poor in quality and only suitable for industrial purposes, but today they can be made attractive enough to use in jewellery.

The CEO of Pure Grown Diamonds wearing a three-carat diamond made using the CVD method

## MAKING A SYNTHETIC DIAMOND

**The HPHT method replicates the natural diamond-making process to create gems in a laboratory**




**1 GROWTH CELL**
This contains a tiny diamond seed surrounded by molten metal with carbon atoms dissolved in it.

**2 CARBIDE ANVIL**
A pair of heavy-duty pistons squeeze down onto the growth cell to produce the required high pressure.

**3 CARBIDE RING**
This solid ring helps create the necessary pressure for the carbon atoms to deposit onto the diamond seed.

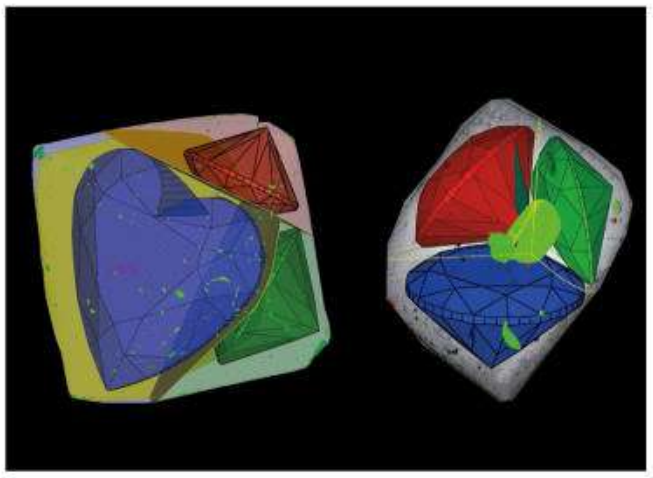
**4 PRESSURE-TRANSMITTING MEDIUM**
This ensures that the forces created by the pistons and ring are transmitted uniformly to the growth cell.

**5 GRAPHITE HEATER**
This produces the other factor besides pressure that's needed for diamond growth: a high temperature.

© NASA / Alamy / Getty

# CUTTING AND POLISHING DIAMONDS

**Turning a rough, newly mined diamond into a piece of jewellery is a fine art**

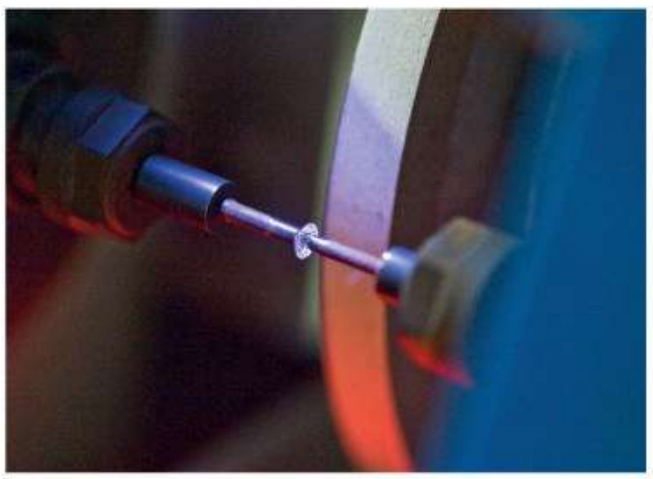


## 1 PLANNING

The first step is deciding the most efficient way to divide and cut a particular diamond. Today's cutters use state-of-the-art technology to help them visualise this.

## 2 CLEAVING

If the plan involves making two or more finished gems from a single rough diamond, it first has to be cut or split into the necessary pieces.



## 3 LASER CUTTING

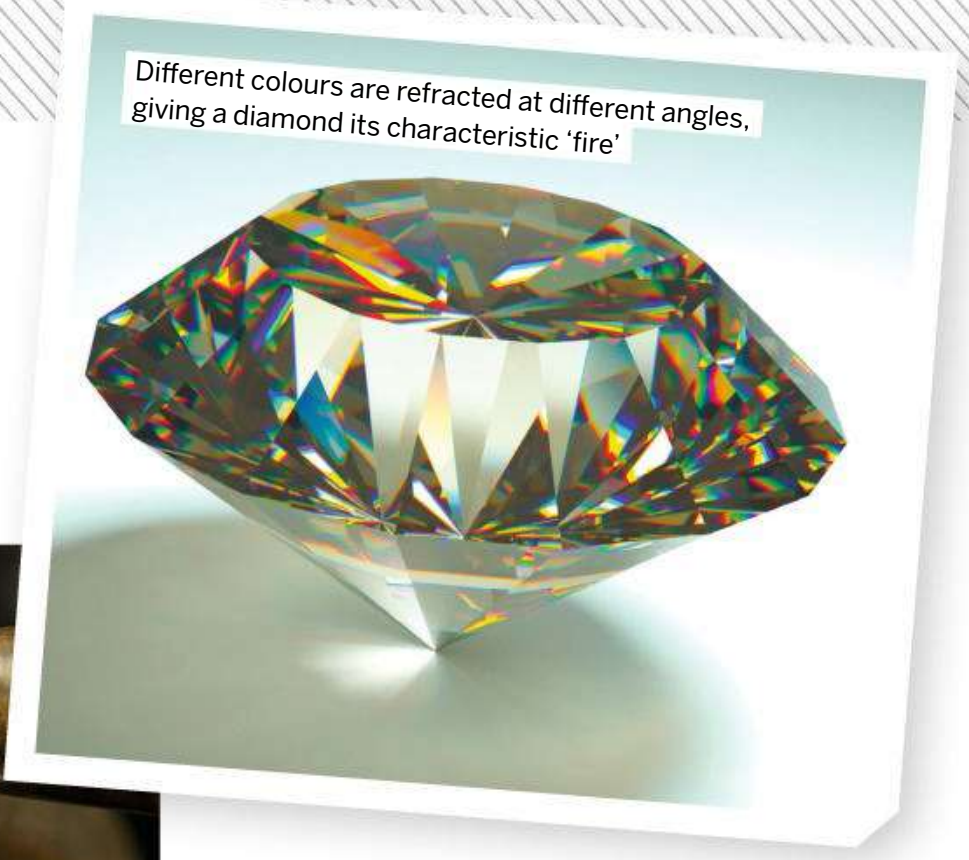
The next step is to carefully cut away unwanted parts of the diamond to produce the required shape – something that can be done using a laser today.

## 4 POLISHING

This step is self-explanatory, but not as easy as it sounds. Because diamond is so hard, it can only be polished using fine diamond powder.

## 5 GRADING

Once the diamond has been finished, it's ready for grading according to the 'four Cs': colour, clarity, cut and weight in carats.



Different colours are refracted at different angles, giving a diamond its characteristic 'fire'

Cutting glass is one of the best known uses of diamond

## THE SCIENCE BEHIND THE SPARKLE

**Perhaps the most magical feature of a diamond is its sparkle – the enthralling way it reflects light when illuminated. But it's not really magic, just a combination of the diamond cutter's art and the science of optics. From the latter point of view, the two key processes are reflection and refraction. The first of these simply refers to the way light hitting one of a diamond's facets – either from outside or internally – can be reflected, as if by a mirror. As for refraction, that's most commonly encountered in the context of lenses, where it refers to the way a lens bends light. But the same thing happens when light travels between any two transparent substances, including air and diamond. The skill in diamond cutting is to produce facets at just the right angles so that the combined effects of reflection and refraction send as much light as possible towards the viewer.**

A diamond cutter works hard to get the perfect sparkle

**DID YOU KNOW?** The intense flashes of light seen when a diamond is tilted or moved are called scintillation

# HOW DIAMONDS REFLECT LIGHT

**The key to diamond cutting is to reflect as much light as possible**

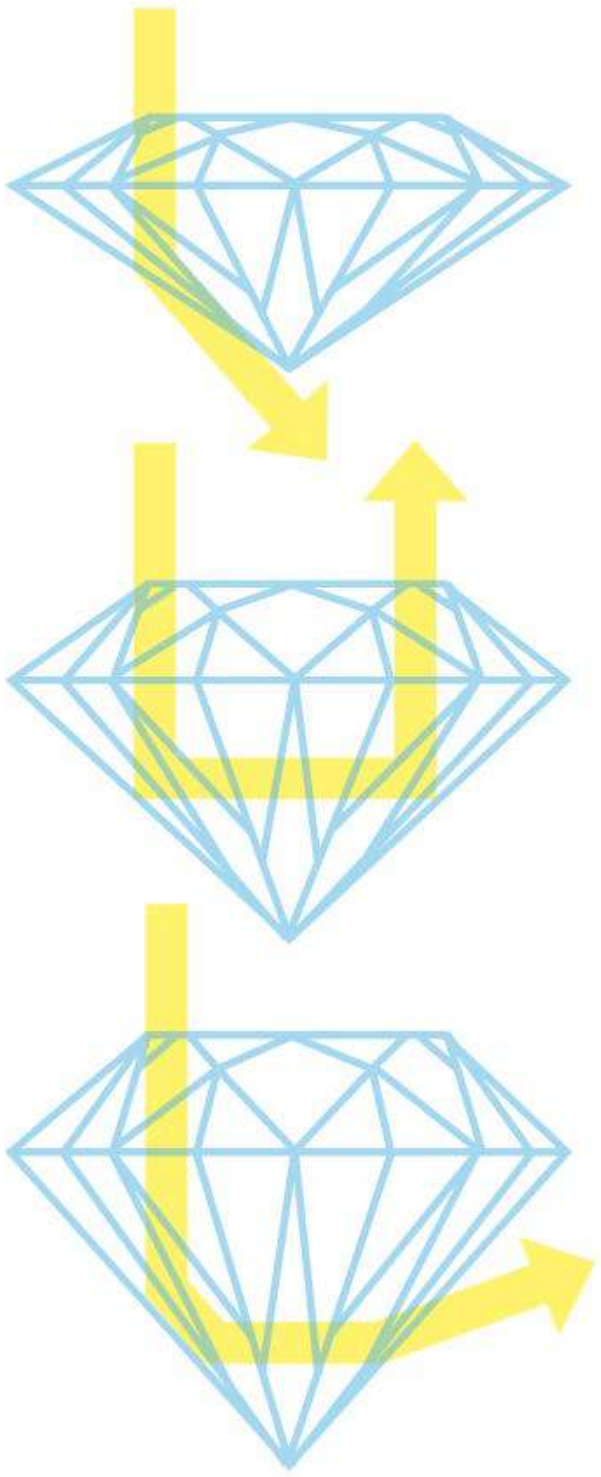
**Did you know?**

Queen Elizabeth's Imperial State Crown has 2,868 diamonds

**SHALLOW CUT**
If the cut is too shallow, some light is refracted through, rather than reflected from, the bottom of the crystal.

**IDEAL CUT**
In an ideal case, all the light entering the diamond is reflected back out again, with none lost to refraction.

**DEEP CUT**
Here light reflected from one side is bounced across to the other side, where it is again lost through refraction.



# FOUR FAMOUS DIAMONDS

**CULLINAN DIAMOND**
Later cut into smaller pieces, this was the world's largest gem-quality diamond when found in South Africa in 1905.

**BLACK ORLOV**
This dramatic-looking black diamond is said to be responsible for the deaths of two Russian princesses and a diamond dealer.

**HOPE DIAMOND**
Another 'cursed' diamond, the legend – or perhaps marketing ploy – is that it was stolen from the statue of a goddess.

**SEWELO DIAMOND**
At 1,758 carats, this is the largest as-yet-uncut diamond, having been found in Botswana in April 2019.

# WHAT DIAMONDS ARE USED FOR

**Many poorer quality diamonds end up being used not in jewellery, but in industrial applications, with small diamond particles embedded into saw blades, drill bits and grinding wheels. Loose diamond powder can also be used to polish objects made of hard stone, and this may even predate the ornamental use of diamonds. There's evidence that Chinese craftsmen were using diamond powder in this way as far back as 4,500 years ago.**

**More recently, diamonds have found their way into high-end electronic products, both as a means to remove unwanted heat and in loudspeaker cones that can vibrate rapidly without deforming. They're also used to make high-brightness lasers that are especially suited to beaming power over long distances, for example in space communication.**

A selection of diamond-coated tools for cutting and grinding

© Alamy / Getty / Wiki: Firebrace

# HOW CANCER IS DIAGNOSED

**This disease can affect any part of the body, requiring robust methods to detect and classify it**

WORDS AILSA HARVEY

**DID YOU KNOW?** More than 2 million women in the UK are screened for breast cancer each year

Cancer research suggests that by 2040, 27.5 million people will be diagnosed with cancer each year. Four of the most common types of cancer are breast, lung, prostate and bowel cancer. However, there are more than 200 types in total. With such a broad range of cancers impacting almost any area of the body, how are these different types spotted and diagnosed?

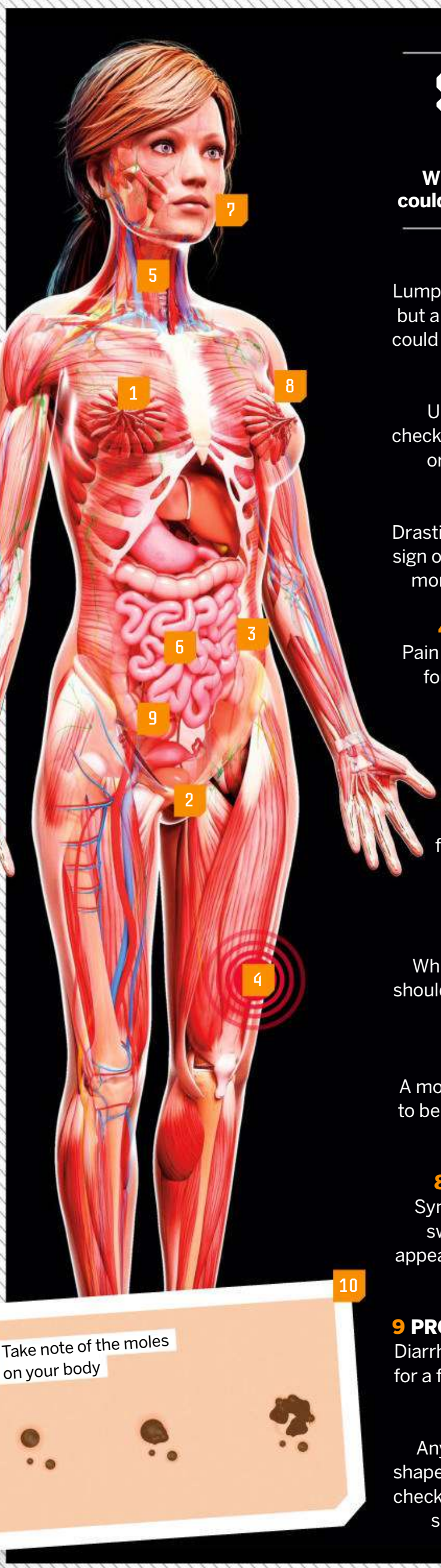
Any cancer that's caught early on in its progression is easier to treat. Cancer is the abnormal and uncontrolled growth of cells in the body. Because of the nature of cancer, the longer these signs are ignored, the further cancer can spread in the body. To control cancer as much as possible, doctors recommend that people stay aware of their bodies.

One of the best ways to detect cancer early on is to report any suspicious signs. By knowing how your body looks and feels, and by checking yourself regularly, you're more likely to see or feel any symptoms of cancer early on. Any abnormal changes in the body may be worth getting checked out by a doctor, though the fear of being diagnosed with cancer is enough to make some people ignore these signs for as long as possible. In most instances, it won't be cancer. But if it is, then spotting it in its initial stages can make treatment easier and even save your life.

Sometimes cancer can exist in the body without showing any obvious signs. In order to spot cancer and treat it at an early stage, cancer screening is available to people without any symptoms at all. Cancer screening involves tests to spot the very early development of cancer. This includes colonoscopies to detect colorectal cancer, scans that analyse the lungs of heavy smokers, breast cancer screening using X-rays, cervical cancer screening and blood tests.

**Did you know?**

Cancer is caused by mutations in cells' DNA




# SIGNS OF CANCER

**What changes in the body could be cancer warning signs?**

**1 LUMPS**
Lumps can occur for many reasons, but a new lump or thickened tissue could be signs of cancerous growth.

**2 BLEEDING**
Unusual bleeding should be checked, such as coughing up blood or blood in urine and stools.

**3 WEIGHT LOSS**
Drastic, unexplained weight loss is a sign of cancer; cancerous cells burn more energy than healthy cells.

**4 CONTINUOUS PAIN**
Pain that continues for more than four weeks is a warning sign.

**5 VOCAL AND BREATHING CHANGES**
This symptom is most common in smokers or ex-smokers. If this continues for more than three weeks, you should see a doctor.

**6 BLOATING AND INDIGESTION**
While indigestion is common, it shouldn't happen very frequently or cause significant pain.

**7 UNUSUAL ULCER**
A mouth ulcer that doesn't appear to be going away could be a sign of mouth cancer.

**8 COMMON CANCERS**
Symptoms include new lumps, swelling, pain and change in appearance, or dull or sharp pain in the breasts or testicles.

**9 PROLONGED BOWEL ISSUES**
Diarrhoea or constipation that lasts for a few weeks should be reported.

**10 MOLE CHANGES**
Any mole that changes colour, shape or size is unusual. You should check your skin regularly in order to spot any of these changes.

Some signs of cancer can be seen in the blood




© Getty / Alamy

Some cancers, in the brain and bone, show up better on an MRI than a CT scan

# TESTING FOR CANCER

## LAB TESTS

**A liquid biopsy is the analysis of a patient's blood for traces of DNA from cancer cells**

### 1 EXOSOMES

Exosomes are tiny sacs that deliver molecules between cancer cells. These can contain proteins and lipids that contribute to tumour growth.

### 2 MRNA

Messenger ribonucleic acid (mRNA) molecules carry the code needed to produce a cancer cell's proteins.

### 3 DNA MUTATIONS

A mutation in a DNA sequence can be detected in a biopsy. Some are known to contribute to cancer and are called cancer-critical genes.

### 4 FUSION GENES

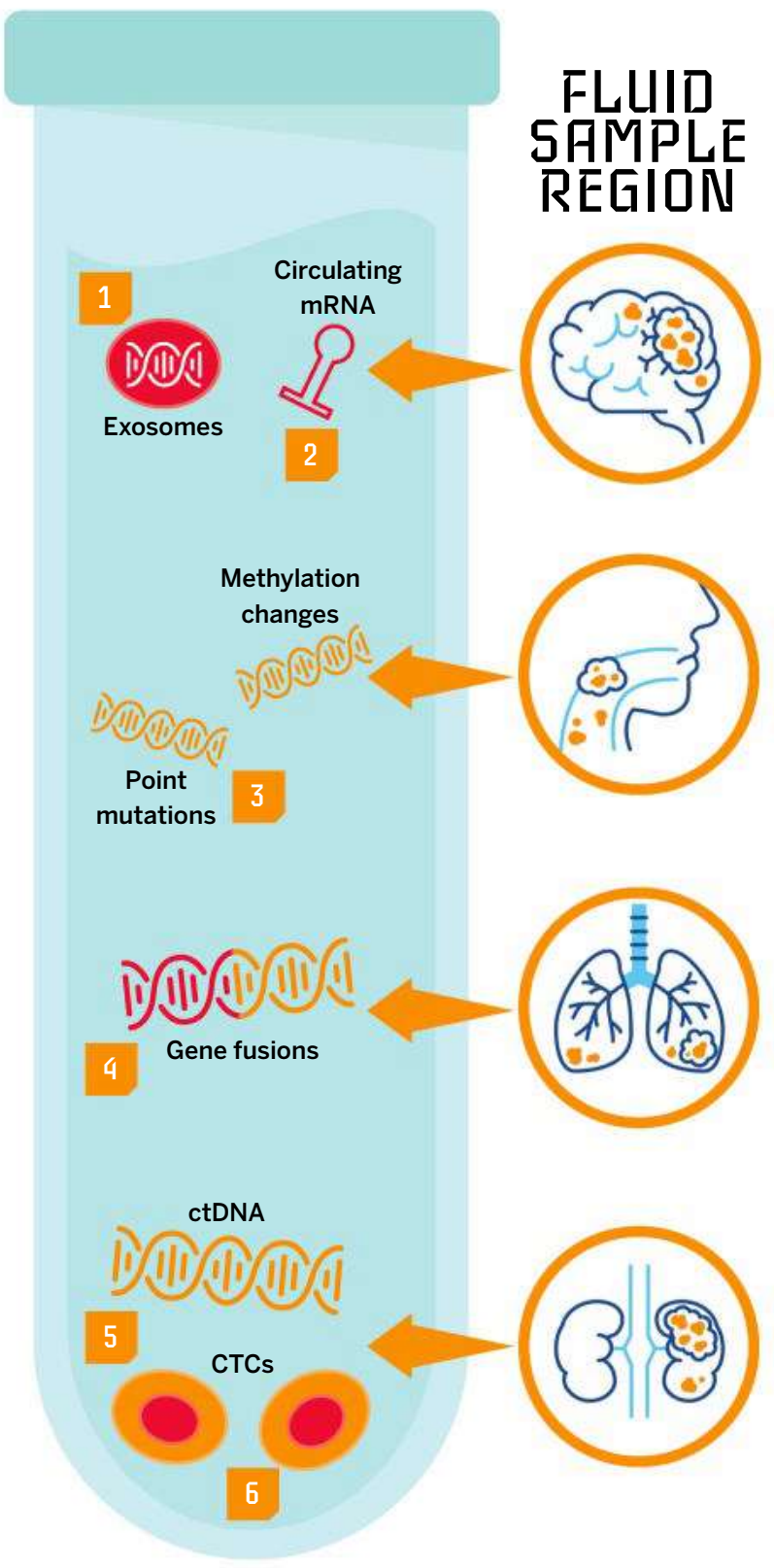
It's possible for two separate genes to join together. Some fusion genes cause tumours as they produce more abnormal proteins.

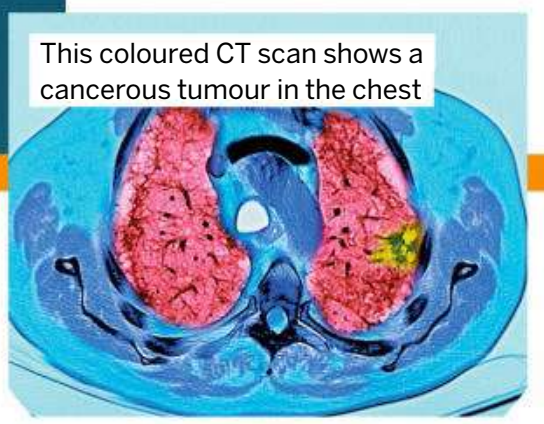
### 5 CTDNA

ctDNA stands for circulating tumour DNA. When cancer cells die, they release their DNA into the bloodstream.

### 6 CTCS

Circulating tumour cells (CTCs) are those that have detached from a tumour and can be detected in the blood.



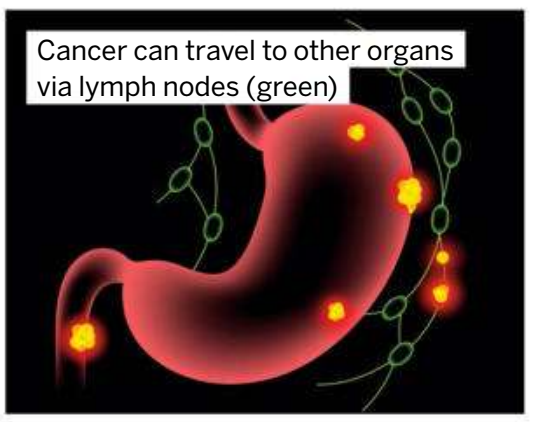



This coloured CT scan shows a cancerous tumour in the chest

## IMAGING TESTS

**To get confirmation of whether someone has a cancerous tumour, or to find out whether cancer has spread, doctors need to observe inside the body. To do this, various imaging tests are used, providing a full visual picture. Rays of different wavelengths scan the body. When they reach the tissues of the body, the energy pattern of the ray is changed. These changes are displayed as an image.**

**Magnetic resonance imaging (MRI) uses magnetic fields and is the preferred test used to diagnose brain tumours. Computed tomography (CT) scans produce images of the inside of the body by taking X-rays from different angles. Some tumours don't show up as well on X-rays and require an ultrasound. This test involves sending high-frequency sound waves through the body. The waves create echoes as they bounce off organs and tissue, producing a computerised outline of any tumours.**



Cancer can travel to other organs via lymph nodes (green)

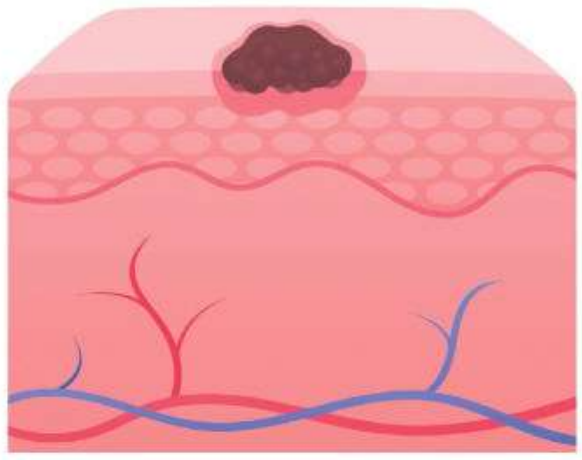
## WHAT IS THE STAGING SYSTEM?

**'Cancer' is a very broad diagnosis of what's happening inside a person's body. This can vary from localised cancer in its early stages to cancers that are widespread in the body. Depending on how much cancer there is and where in the body it's located, different treatment is needed. While there are different staging systems used to classify cancer, the TNM system is the most common. Cancers are described using these letters to provide information on the tumour size (T), whether it has spread to nearby nodes (N) or has spread to other parts of the body – or in other words has metastasised (M).**

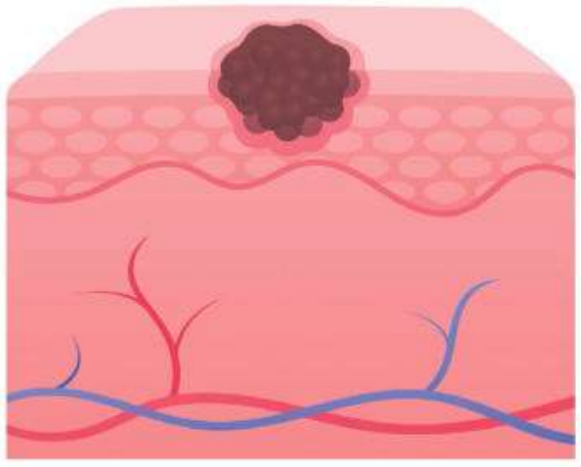
**DID YOU KNOW?** The most commonly diagnosed cancers in men are prostate, lung and colorectal

# 5 STAGES OF DIAGNOSIS

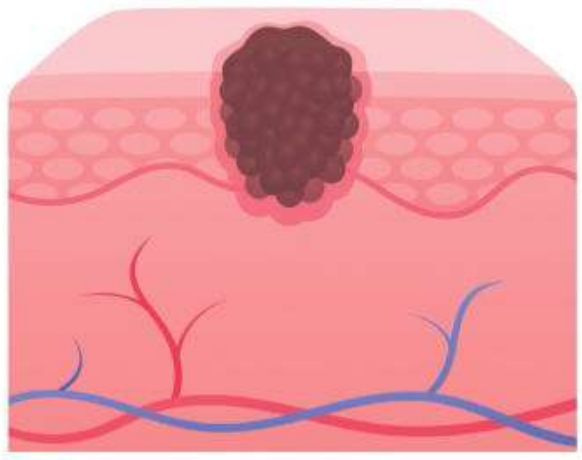
## A cancer's stage describes how advanced it is



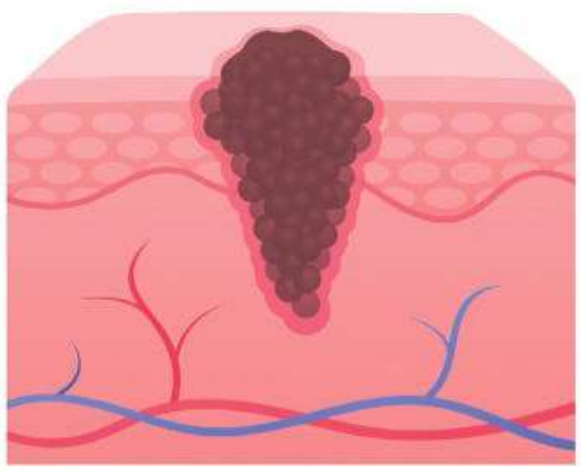
1 **STAGE 0**
This means there's no cancer. However, the abnormal cells still hold the potential to become cancerous.



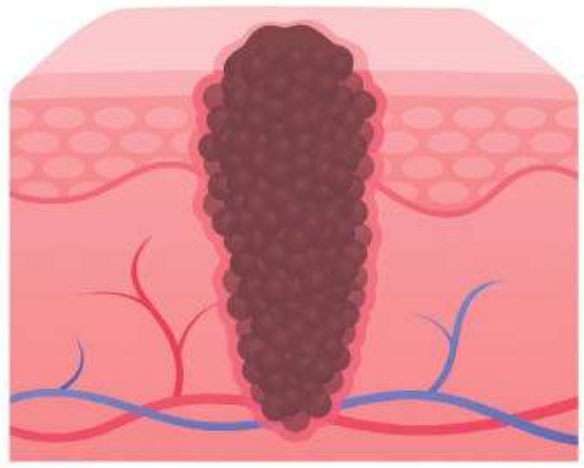
2 **STAGE I**
The cancer is in its earliest stage and is confined to a small area of the body. It's easier to treat at this early stage.



3 **STAGE II**
Stage II cancer has grown in the surrounding tissue, but hasn't spread elsewhere in the body.



4 **STAGE III**
At this stage, the cancer may have spread to the surrounding tissue and lymph nodes.



5 **STAGE IV**
When diagnosed with stage IV cancer, it's been detected in at least one other organ than where it originated.

**Did you know?**

Smoking is the largest preventable cause of cancer

# WORKING IN CANCER DIAGNOSTICS

**Glycanostics' cofounder Ján Tkáč is developing technology that can detect early stage prostate cancer in the blood. For his work, he was selected as an ESET Science Award winner in 2019**

**What does your research involve?**
We're working on highly accurate diagnostics of several types of cancer by an innovative and unique approach using just a single drop of blood. The uniqueness of our technology lies in the analysis of glycans [complex carbohydrates]; our test is the only one capable of detecting 'healthy' and 'sick' forms of glycans.

**Why did you choose to work in cancer diagnosis, particularly for prostate cancer?**
It's important to focus on diagnostics of cancer types which affect people the most. It was a natural choice to focus on prostate cancer diagnostics, which is very frequent in men. One of the additional drivers to focus on diagnostics of prostate cancer was also the fact that my PhD supervisor Dr Šturdík died from the disease. This is why our incentive is to diagnose such a disease at an early stage with high accuracy.

**What does being an ESET Science Award finalist mean to you?**
The perception that science is important is still low in our society, although the corona crisis helped a little bit in that direction. At the end of the day, usually you don't see the result of your intensive work. It takes a long time until everything clicks and you feel personal satisfaction. It's very important for me to know that the work we are doing is meaningful and appreciated by the public and experts. To receive the award personally from Nobel Prize laureate professor Erwin Neher was a cherry on the cake.

**The ESET Science Awards recognise the very best Slovak scientific achievements, innovations and breakthrough inventions. For more information about the awards, head to the ESET Science Awards website: esetscienceaward.sk/en**

© Getty / Alamy

# INSIDE A BIONIC EYE

## With over 160 million people suffering from some type of sight loss, bionic eyes could be the solution to one of the most pressing medical issues of our time

WORDS **MARK SMITH**

In the TV series *Star Trek: The Next Generation*, the Enterprise's blind chief engineer Geordi La Forge wore a device that allowed him to see – but that was in the fictional 24th century. Technology that can replicate the functions of the human eye has always remained firmly within the realms of science fiction, until now that is. Advances in science have seen the creation of bionic eyes that, for the very first time, are restoring hope to the many people who are unable to see or whose vision has deteriorated due to injury, illness or genetics. With nearly 40 million people suffering from blindness worldwide and another 124 million affected by low vision, the need for new solutions is pressing.

A healthy eye takes in light through the pupil, and a lens focuses that light onto the back of the eye, where there is a thick layer of light-sensitive tissue called the retina. Cells called photoreceptors turn the light into electrical signals which travel down the optic nerve to the brain, which then interprets the images. But problems occur when part of that system is interrupted, often by degenerative diseases that can damage parts of the retina. This is where technology steps in to bridge the gap in the part of the process which is missing or damaged.

There are different types of bionic eyes in development, and indeed some are not eyes at all, but types of glasses worn like traditional spectacles. It was surgeons at Manchester and Moorfields eye hospitals who made history in 2009 by delivering the world's first trial of the Argus II bionic eye in patients with retinitis pigmentosa, a degenerative eye disease. They implanted them in ten patients with sight loss. It helped them recognise shapes and patterns, and in 2013 the US Food and Drug Administration legally approved the device for use.

The technology has continued to evolve, and last year researchers at Keck School of Medicine of the University of Southern California created an advanced computer model to mimic the human retina. It replicates the shapes and positions of millions of nerve cells and could help bring colour vision and improved clarity to the technology. Meanwhile, scientists at the University of Sydney and the University of New South Wales recently carried out successful trials of the Phoenix99 bionic eye in sheep to see how the body heals when it is implanted with the device. The researchers said there were no unexpected reactions and expect it could safely remain in place for 'many years'. The work will now pave the way for human trials.

One of the problems with the technology is that it can be relatively bulky, so the race is on to find new ways to power bionic eyes. Scientists at the Harbin Institute of Technology in China and Northumbria University recently developed a low-power system to control the synaptic devices in bionic eyes, with lead professor PingAn Hu describing it as a "significant breakthrough". Work to refine it continues, but one thing's for sure, when it comes to this type of tech, the future is in the eye of the beholder.

Geordi La Forge's space-age visor was able to transfer images directly into his brain

AR ZONE
SCAN HERE



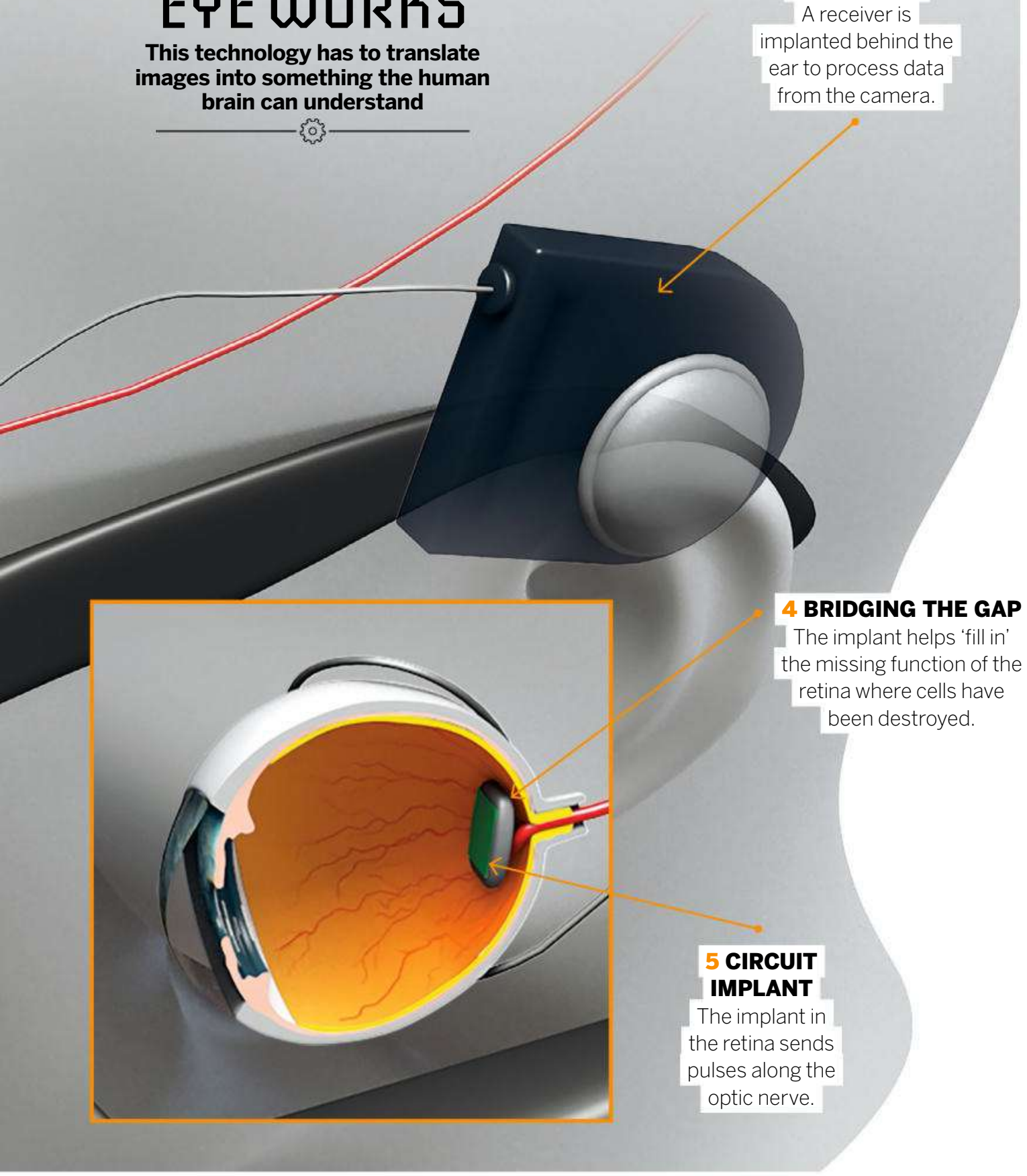

**Did you know?**

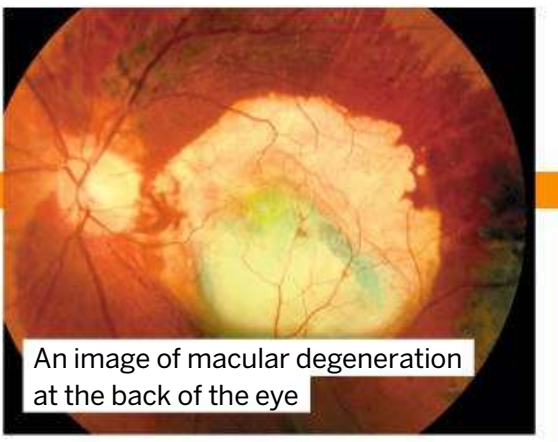
**Your eyes focus on 50 different objects every second**

**DID YOU KNOW?** The Argus II device has been implanted in the eyes of more than 350 people

# HOW A BIONIC EYE WORKS

**This technology has to translate images into something the human brain can understand**





An image of macular degeneration at the back of the eye

## VISION-DESTROYING ILLNESSES

**There are a range of conditions – some which are picked up due to the ageing process and others that may be inherited – that can cause sight deterioration. Bionic eyes work by 'filling in the blanks' between what the retina perceives and how this is processed in the brain's visual cortex. That breakdown occurs in conditions that impact the retina, so it's largely these conditions that bionic eyes could help treat. One such disease is retinitis pigmentosa, a group of rare genetic disorders that involves a breakdown and loss of cells in that part of the eye. Another condition is age-related macular degeneration (AMD), an eye disease that can blur someone's central vision. This condition occurs when ageing causes damage to the macula, the part of the eye that controls sharp straight-ahead vision.**

Second Sight's Brian Mech wearing the Argus II

## A WORLD FIRST

**The first patient to receive a bionic eye was grandfather Keith Hayman in 2009. He was in his 20s when he was diagnosed with retinitis pigmentosa, and he went blind several years later. After being fitted with the bionic eye at Manchester Royal Eye Hospital, he was able to see the difference between light and dark and could detect people moving. He said: "It means I can see my grandchildren for the first time. When they come round to see me they wear white T-shirts to help me keep an eye on them. I couldn't tell you much about what they look like, but at least I can see them coming now!"**

Elias Konstantopoulos wears a set of bionic eyeglasses that allow him to see

Dilek Umran Ozturk after receiving the Argus II bionic eye retina implant surgery

© Getty / Illustration by Adrian Mann

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NCC-1701

**DID YOU KNOW?** The speed of light in a vacuum is 186,282 miles per second, far faster than anything else can travel

# COULD WE BUILD THE USS ENTERPRISE?

## Discover the real-world and theoretical technologies of *Star Trek*'s flagship spacecraft

WORDS **SCOTT DUTFIELD**

Launched into space from the mind of creator Gene Roddenberry in the 1960s, the USS Enterprise NCC-1701 was the very first *Star Trek* spacecraft to reach warp speed on television screens around the world. The ultra-fast, near-invisible and sometimes-time-travelling Constitution-class starship was the most advanced spacecraft at the time of its launch in fictional 2245. Built in space, the Enterprise is a feat of make-believe engineering. It's estimated that the spacecraft would weigh more than 4 million tonnes and house a crew of 430. In comparison, the heaviest human-made object to venture into space is the International Space Station (ISS), which has a mass of around 419 tonnes. China is reportedly researching the possibility of constructing a colossal spacecraft measuring up to 0.6 miles in length – this would absolutely dwarf the ISS, which is only 110 metres long.

Engineers still have 233 years to achieve Roddenberry's vision for space exploration, and several scientific breakthroughs suggest that we might be heading towards a spaceship that's reminiscent of the Enterprise. As a Constitution-class Starfleet Federation starship, the main role of the Enterprise is to venture on intergalactic exploration and diplomatic missions. To assist the crew on their journeys of discovery, the ship is equipped with an array of advanced scanners and sensors.

Before descending upon a new world, the crew aboard the Enterprise flipped a few switches and scanned the planet below for signs of life. It's a pretty handy gadget to have when searching for new life, but one that seems unrealistic. However, scientists are one step closer to making this technology a reality.

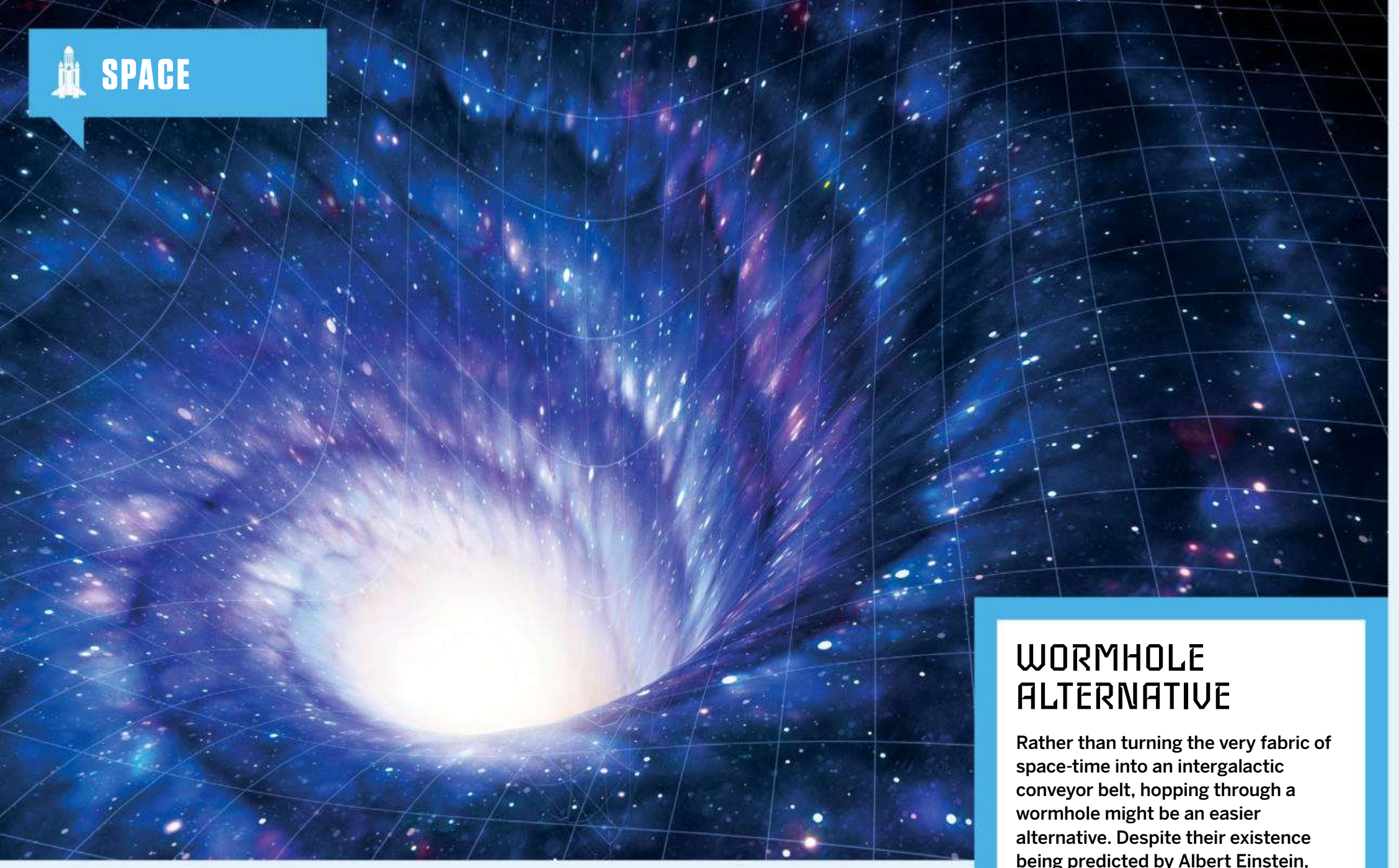
Researchers have discovered that the biochemistry of all life forms interacts with light in a way that inorganic or artificial materials don't. For example, when light hits the long chains of carbon molecules that make up amino acids – the building blocks of proteins – it becomes circularly polarised. This means that it travels in either clockwise or anticlockwise spirals. Scientists could theoretically observe and identify this light interaction in the hope of discovering new life forms from the observatories on spacecraft, such as from future space-based telescopes like the Large Ultraviolet Optical Infrared Surveyor (LUVOIR).

**Did you know?**

**Robert April was the first captain of the USS Enterprise**

Enterprise overlooking a planet

© Alamy



# FUELLING THE FUTURE

## How to make a spaceship move faster than the speed of light

One of the most iconic abilities of the USS Enterprise is its ability to zip from one end of the galaxy to the other in mere moments using its fictitious warp drive. Human technology is currently nowhere near advanced enough to replicate the Enterprise's warp drive. However, the theory behind building one has been around since the early 1990s. To achieve speeds faster than the speed of light, physics' natural speed limit, theoretical physicist Miguel Alcubierre proposed that we must bend the fabric of space-time.

Space-time can be imagined as a sheet of rubber on which all matter sits, creating dips in the rubber relative to their masses. Alcubierre proposed that if space-time could be folded in front of a spaceship and then expanded behind it, the ship could travel much faster than the speed of light, achieving 'warp speed'. This bending of space-time would theoretically continue to move in a wave and act as a conveyor belt, carrying the spaceship along it.

To achieve such space-time manipulation, Alcubierre suggested an enormous amount of negative mass, a phenomenon rarely created in laboratories and seen as vacuum energy in space. The amount of negative mass needed to facilitate Alcubierre's warp drive would have to be equivalent to the mass of a huge star, distributed in a ring around a spacecraft. This hypothetical ring of negative mass would create a 'warp bubble', which would distort space-time and transport any spacecraft within it.

**Did you know?**

**More than 600 people have ventured into space**

Although Alcubierre's theory requires negative mass, recent research out of Göttingen University, Germany, offers a new area of physics for researchers to explore potential for warp power. In 2021, physicist Erik Lentz hypothesised that positive mass and energy could also provide the necessary requirements to construct a warp bubble. Instead of the solid ring of negative mass detailed in Alcubierre's theory, Lentz proposes that layering rings of extremely dense fluid, similar to the composition of a neutron star's interior, would yield the same result. With the ability to bend space-time, those inside the warp bubble could travel through space faster than the speed of light without breaking any physics laws. Much like the ability to walk freely in an aeroplane, a warp bubble would theoretically allow a spaceship and its crew to move around without feeling the effects of warp speed.

But there are several questions that remain unanswered about building a real-life warp-capable vessel, such as how to control its direction and distance, as well as how a ship would exit a warp bubble. In *Star Trek*, to fuel the warp drive and create enough energy to bend space-time, the USS Enterprise takes advantage of the annihilation reaction between matter – in the form of deuterium, a real-world isotope of hydrogen – and antimatter, which is regulated by a fictional crystal called dilithium. The 'electro-

### WORMHOLE ALTERNATIVE

**Rather than turning the very fabric of space-time into an intergalactic conveyor belt, hopping through a wormhole might be an easier alternative. Despite their existence being predicted by Albert Einstein, researchers still aren't sure if they really exist. In a nutshell, a wormhole is a tunnel that connects two openings in folded space-time. Entering at one end would theoretically see you shoot out the other end much faster than the speed of light travels, having travelled a tremendous distance. The only trouble is that we just don't know how it would work, and we aren't even close to creating an artificial wormhole. Scientists are looking throughout the Milky Way, inside black holes and even in fluctuations of space-time called quantum foam for wormholes, and thus far they've turned up empty handed. The sooner one is discovered and studied, the closer we might be to using them as space-time highways.**

**DID YOU KNOW?** The most distant spacecraft from Earth is around 14.5 billion miles away

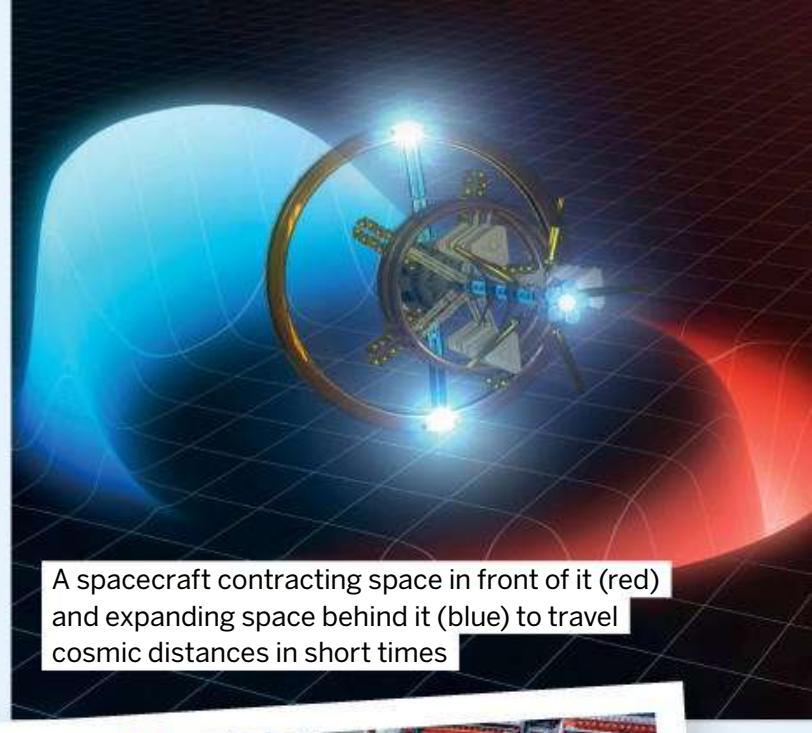
plasma' energy released from this reaction creates the necessary warp bubble to manipulate space-time and move the ship. The biggest hurdle to overcome in using annihilation reactions for energy is producing enough antimatter to power a warp drive.

As the name suggests, antimatter is a mirrored and opposing version of normal matter. For example, an electron has a negative charge, so its antimatter partner has the same mass but an opposite positive charge, called a positron. In order to create antimatter, particle accelerators such as the Large Hadron Collider fire high-speed particles at one another to release antimatter.

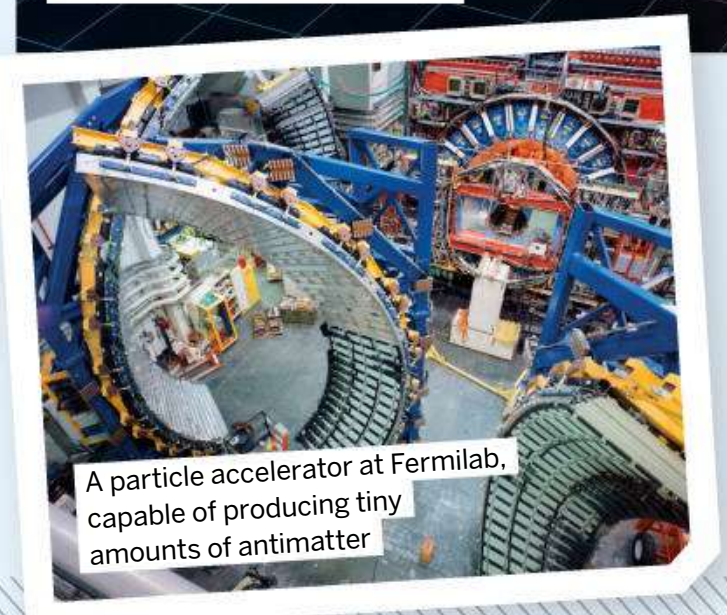
> "Despite quantum woes, research into antimatter spacecraft is still ongoing"

However, there are several physical issues with using antimatter as a fuel source. Firstly, the yield of its production is very low. The Fermi National Accelerator Laboratory (Fermilab) can only produce enough antimatter in an hour to power 1/1000th of a watt, and therefore 100,000 Fermilabs would be required to power a single light bulb. Due to the fact that antimatter annihilates when it comes in contact with regular matter, storing it is near impossible, as everything is made up of matter.

Despite these quantum woes, research into antimatter spacecraft is still ongoing. One of the latest advancements in antimatter propulsion is NASA's proposal for a space probe that will travel all the way across our stellar neighbourhood to a relatively nearby star 4.2 light years away called Proxima Centauri, which will be done using an annihilation accelerator. But until scientists can successfully mass produce and store antimatter, powering a spacecraft that resembles the Enterprise remains firmly in the realm of science fiction.



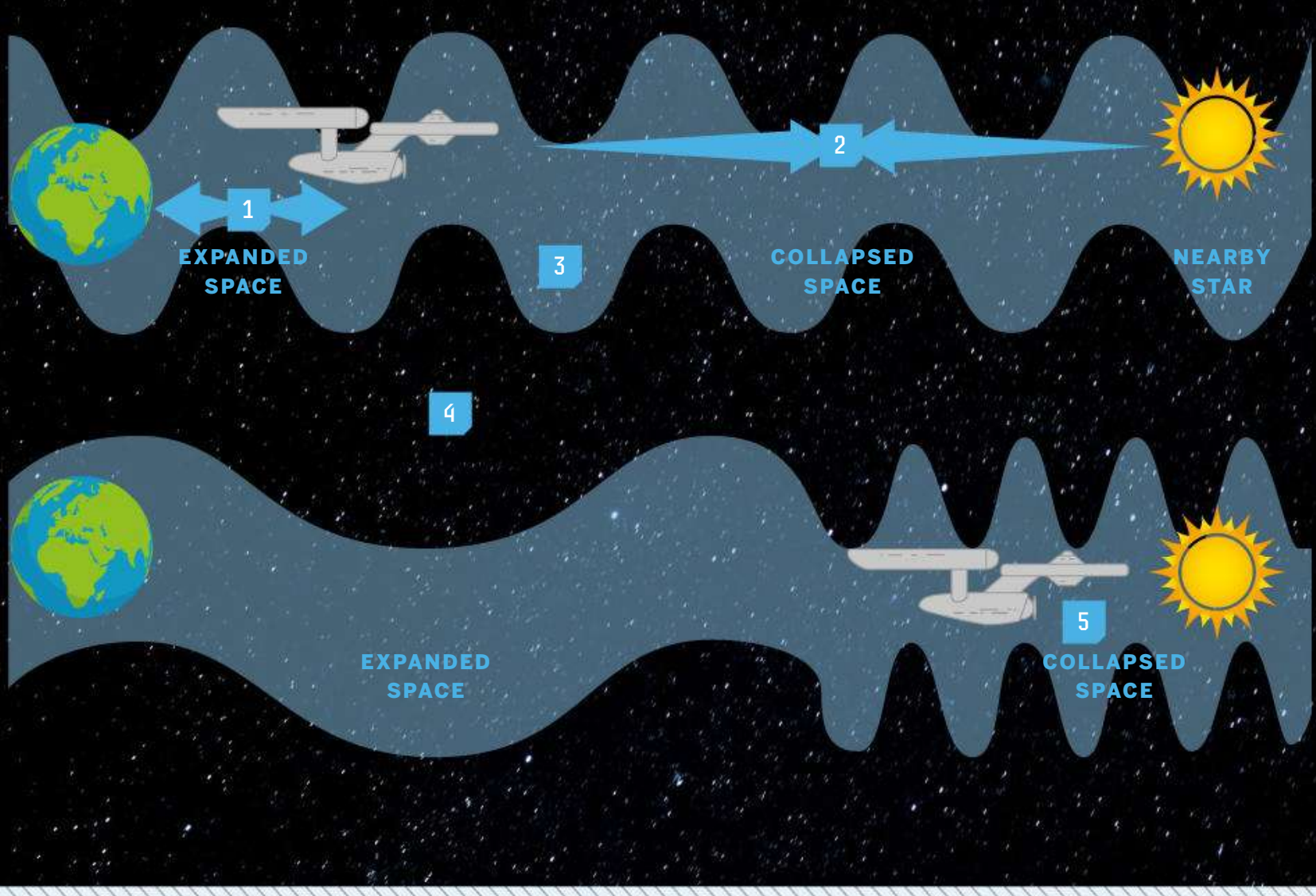
A spacecraft contracting space in front of it (red) and expanding space behind it (blue) to travel cosmic distances in short times



A particle accelerator at Fermilab, capable of producing tiny amounts of antimatter

## RIDING THE WAVE

**How the Enterprise could theoretically move through space-time**




**1 EXPANSION**
The space-time behind the warp bubble expands.

**2 CONTRACTION**
The space-time in front of the warp bubble contracts.

**3 WARP BUBBLE**
The warp bubble, also referred to as a warp field, is an area of extreme spatial curvature that bends space-time.

**4 SPACE-TIME**
Space-time is the conceptual model that combines the three dimensions of space with the fourth dimension of time – the fabric of the universe as we know it.

**5 MOVEMENT**
The warp bubble and any spaceship within it moves along space-time due to the conveyor belt-like contraction and expansion of space-time.

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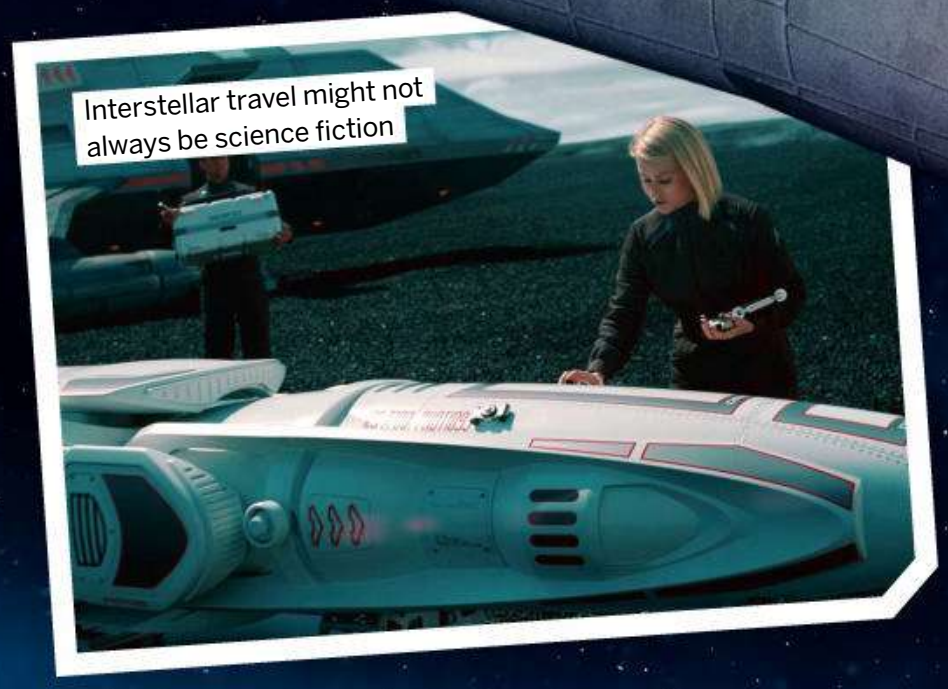



# ALL ABOARD THE USS ENTERPRISE

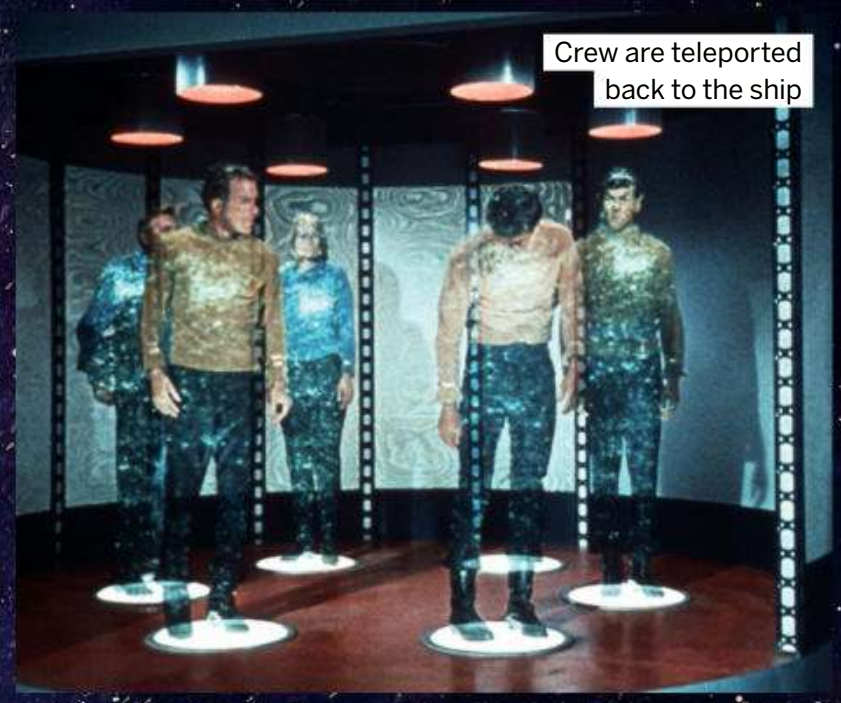
**How this Star Fleet spaceship could be brought to life with real world technology**

**1 DEFLECTOR**
Fending off enemy lasers and withstanding space radiation is an everyday task for the Enterprise. But thanks to the ship's all-encompassing deflector shield, it can withstand such attacks. The closest scientists have gotten to replicating any sort of shielding technology that could protect future spacecraft involves generating a protective electromagnetic field. Much like how Earth shields itself from solar radiation, researchers have found a way to replicate a similar shield against radiation in the laboratory, but its spacecraft applications remain unclear.

**2 HULL**
The spacecraft's hull and body are composed of material made from a fictitious element stronger than diamonds, called tritanium. Its durable properties allow the starship to withstand immense changes in temperature. It's unyielding to the force of warp speed and protects the crew against space radiation. In the absence of tritanium in the real world, engineers heavily rely on aluminium to build spacecraft due to its strong-but-lightweight properties. Some research suggests that plastic could be used as an alternative material to withstand the pressures of space travel.

**3 SICKBAY**
As the medical hub for the Enterprise, the sickbay is filled with healing and sensory technology unlike anything seen in the real world, including medical tricorders. These handheld devices simply scan a patient to reveal any illnesses or injuries. Scientists are closer to this feat of medical engineering with the creation of DxtER, a high-tech device which can detect 34 different medical conditions, including diabetes, pneumonia and tuberculosis, using Bluetooth sensors.

**DID YOU KNOW?** There have been nine different USS Enterprise spacecraft in both film and television







**Did you know?**

There are $10^{82}$ atoms in the observable universe

**4 PHOTON TORPEDOES**

The Enterprise is equipped with 250 deadly photon torpedoes, with these making up its heavy-hitting artillery. Similar to the way the *Star Trek* writers created an annihilation reaction-fuelled warp drive, a photon torpedo uses the same reaction to cause an explosion upon impact with enemy ships. However, like the warp drive, real-world versions of these weapons face the same physical hurdles.

**5 TELEPORTER**

"Beam me up, Scotty" is commonly heard in the transporter room as Captain Kirk and his crew teleport off the Enterprise onto some distant land. As for replicating the technology, scientists have successfully achieved teleportation in laboratory experiments, but only on a quantum level. A 2020 study found that researchers could 'teleport' data over a distance of 27 miles. As for human teleportation, the science of reconstructing all the atoms in our bodies and reconstructing them in the exact order remains science fiction.

**6 ANTIGRAVITY**

Aboard the starship Enterprise, the crew can freely walk around the vessel under the normal gravitational conditions we experience on Earth. This is achieved with gravity plates that line the ship's hull and interior floors, which are able to create an artificial gravity field aboard the ship. Artificial gravity is continually examined by engineers for advancements in space travel, with several suggestions made, like using magnets and electricity to replicate gravity or even constructing a ship that spins to exploit the force of inertia and create artificial gravity.

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© Alamy / Illustration by Nicholas Forder

# WHAT ARE SATURN'S RINGS MADE OF?

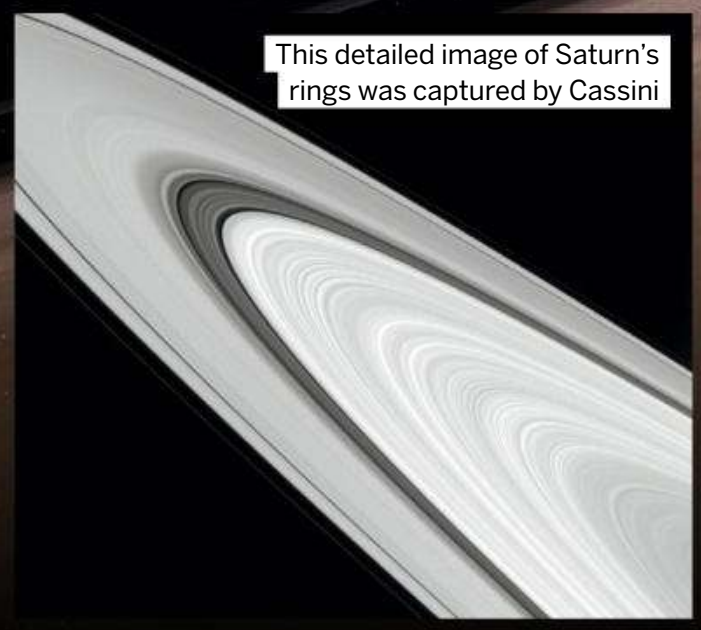
## Billions of icy particles orbit this gas giant to create its iconic shape

WORDS AILSA HARVEY

Viewed from Earth, Saturn's rings appear as a single stationary sheet encircling the planet, but this is far from reality. Spacecraft flybys and other studies have provided detailed images of the rings' arrangement, with photographs revealing information about these unique objects orbiting Saturn. The rings are an array of rocky and icy fragments, which scientists believe to be pieces of moons, asteroids and comets. The leading theory is that these giant rocks were shattered into fragments under the force of Saturn's immense gravity, and the result is a combination of huge, mountain-sized rocks and tiny particles of dust in orbit. Many of the larger objects in the planet's rings are coated in a layer of dust.

Before 1979, scientists thought that Saturn was the only planet in the Solar System with rings. Now we know that's not the case. While the gravity of all the planets attracts smaller objects, drawing them into rings around them, Saturn's rings are the brightest and lie close together. These luminous circles carry space fragments that are much younger than the planet itself. Data from the US-European Cassini mission revealed that the rings could be as young as 10 million years old and no older than 100 million years.

> "The rings are an array of rocky and icy fragments, pieces of moons, asteroids and comets"



This detailed image of Saturn's rings was captured by Cassini

**Did you know?**

Enceladus has at least 101 geysers on its southern pole

### FIRST SIGHTINGS

When Galileo Galilei became the first person to lay his eyes on Saturn's rings in 1610, he was unsure what they were. Looking through his telescope, Galileo described them as ears, as they seemed to appear on opposite sides of the planet. 45 years later, it was a Dutch astronomer called Christiaan Huygens who correctly proposed that these were rings, not ears, that encircled Saturn. Huygens was able to observe finer details of the planet than Galileo, as he had a more powerful telescope.

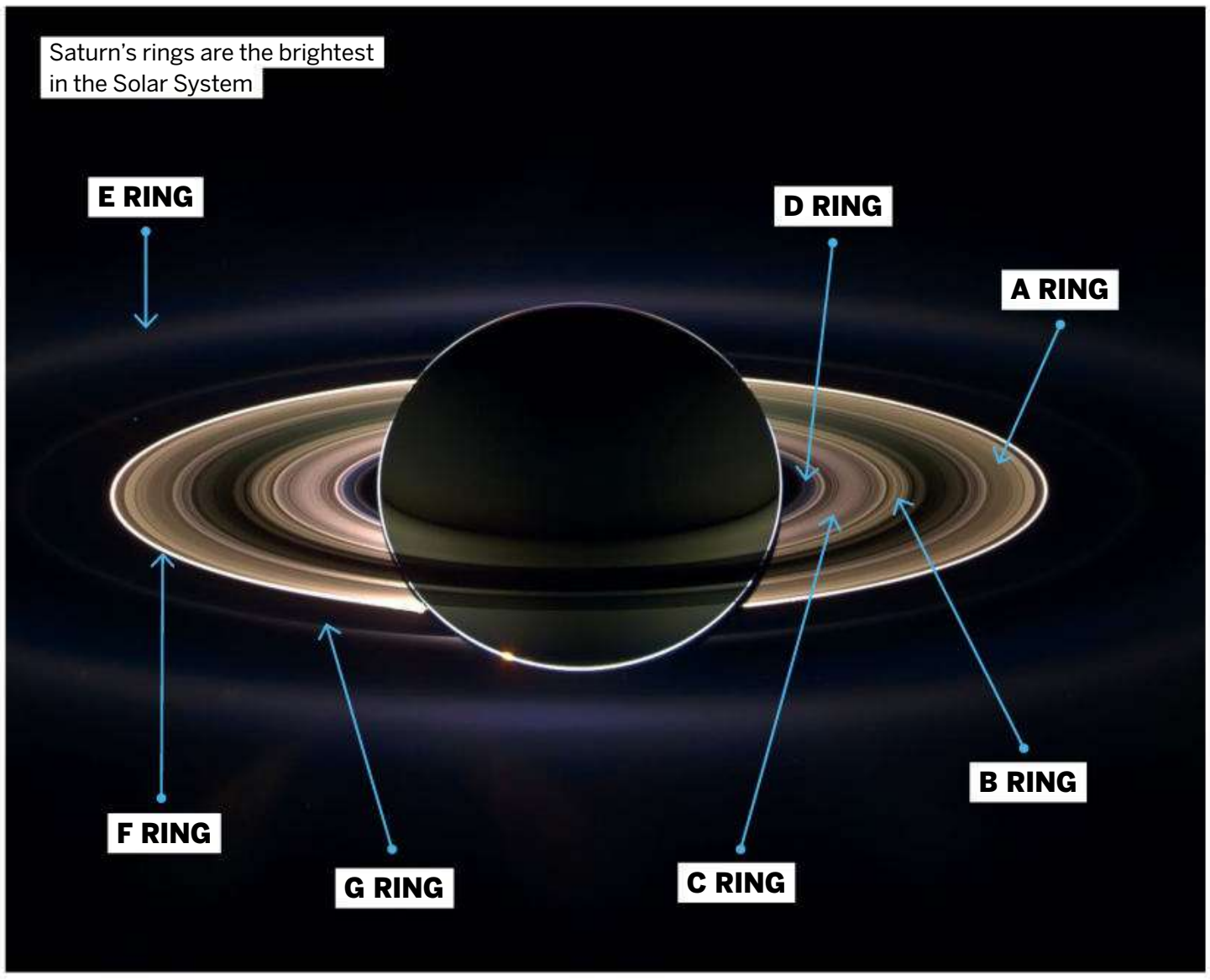
This reconstruction shows the simple telescope used by Galileo

**DID YOU KNOW?** The largest of Saturn's rings spans 7,000 times the diameter of the planet

## SATURN'S BIG SEVEN

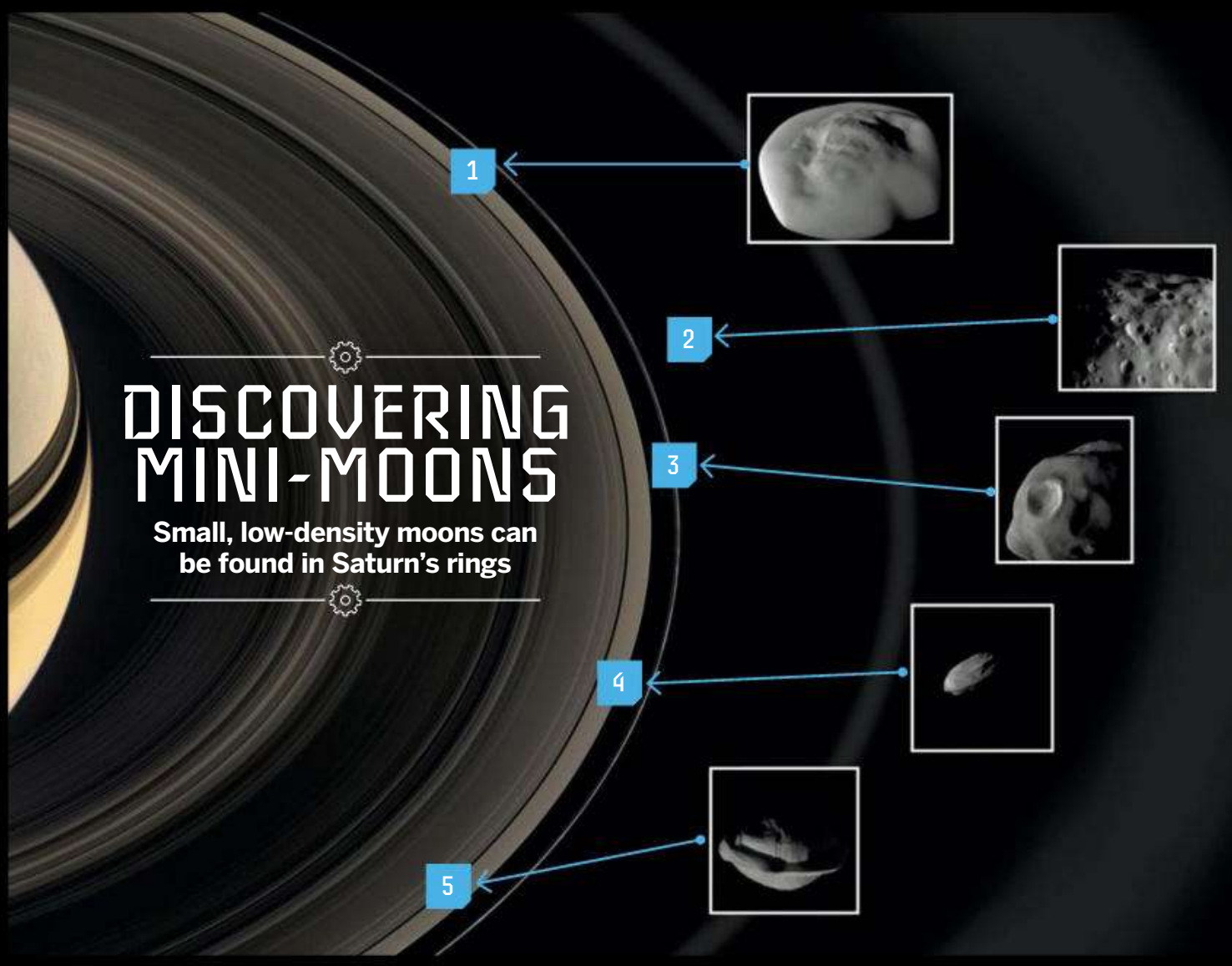
When viewed from a distance, Saturn displays seven distinctive rings. These are simply named as the first seven letters of the alphabet. This ordering doesn't correspond to their distance from the planet, but the order in which they were discovered. Each ring contains orbiting matter, and combined the rings stretch across thousands of miles of space.

The first three rings to be discovered – A, B and C – are the easiest to spot; they're the bright main rings of the planet. Meanwhile, the D ring is extremely dim and lies closest to the planet. The E ring is the largest and outermost ring, spanning about 620,000 miles and lying next to another faint ring, the G ring. Saturn's F ring is made up of many narrow rings. As each one contains multiple kinks and bright clusters, this ring produces a braided pattern.




## DISCOVERING MINI-MOONS

**Small, low-density moons can be found in Saturn's rings**




**1 ATLAS**
**Radius: 9.4 miles**
Orbiting around Saturn's A ring, Atlas has a distinctive UFO shape with a smooth ridge.

**2 EPIMETHEUS**
**Radius: 36 miles**
This moon is covered in several craters over 18 miles wide. It orbits Saturn between the F and G rings.

**3 PANDORA**
**Radius: 25.3 miles**
Pandora is located near Saturn's F ring. The moon is covered in icy debris.

**4 DAPHNIS**
**Radius: 2.3 miles**
The gravitational pull of Daphnis creates ripples at the edge of the Keeler Gap, a significant gap between Saturn's rings.

**5 PAN**
**Radius: 8.7 miles**
This is the closest named moon to Saturn. It lies in the Encke Gap of the A-ring.

© Getty / NASA/JPL/Space Science Institute/ Caltech

The locking system is your car's top security feature, so it has to get the job done properly

# CAR CENTRAL LOCKING EXPLAINED

## Locking the doors on a car may seem simple, but it's a critical vehicle security feature

WORDS **MIKE JENNINGS**

If you're lucky enough to drive, then you'll almost certainly just click a button on your key fob to lock and unlock the car – and if you're not old enough to drive yet, then you've probably seen other people do it. Either way, this car lock technology is now so commonplace that we don't even think about it. But if you do think about it, you'll find plenty of surprising history behind this common car feature.

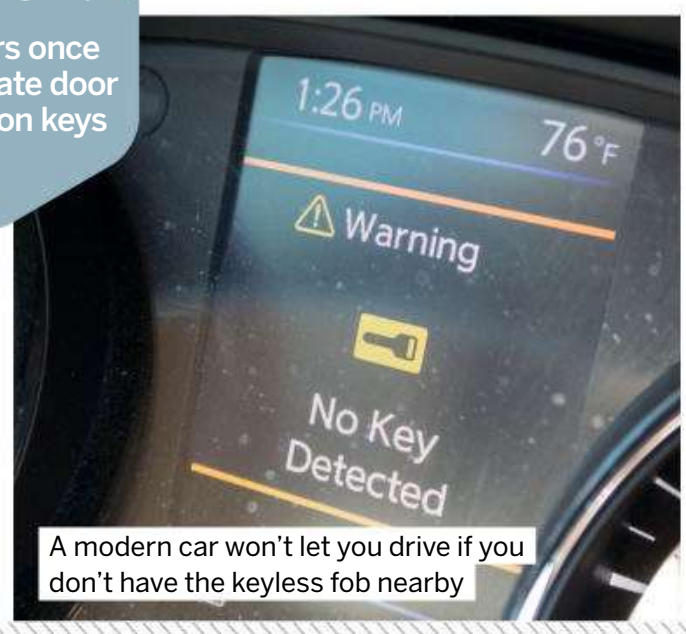
We think about central locking as a relatively modern addition to car security, but the first car with this innovation appeared way back in 1914, and it emerged again in the 1950s. After that, it still took decades for this technology to become a recognisable mainstay feature.

The first cars with central locking allowed drivers to lock or unlock all of their doors with one key. After that arrived, companies tried to innovate with all kinds of experimental car lock systems: in 1980 the Ford Motor Company launched an external keyboard system, and Nissan's 1980s cars had a keypad that lowered the windows. Other cars had methods where you could unlock the driver's door by lifting the handle in a specific sequence that you'd previously programmed.

These days, most central locking systems are much simpler; you can unlock and lock your car doors remotely by pressing a button on a key fob, and you don't have to put the key into the door at all. Most cars also have a separate button to unlock the boot. Central locking and remote locking now form an essential part of car design, and the industry has also moved beyond these with keyless technologies and smartphone processes.

**Did you know?**

**Many cars once had separate door and ignition keys**




A modern car won't let you drive if you don't have the keyless fob nearby

Forward-thinking manufacturers now enable drivers to unlock, lock and start their cars with smartphones

### THE KEY BEHIND KEYLESS

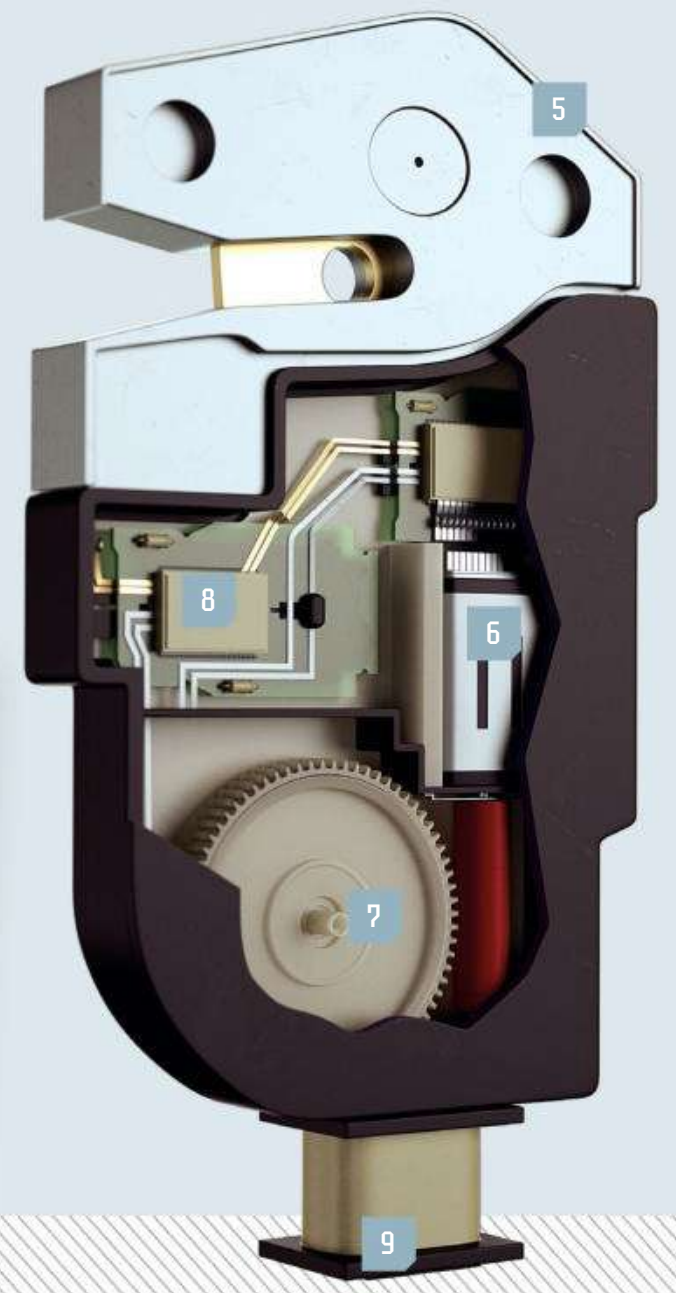
**Most new cars use keyless entry systems where drivers can unlock their car without pressing any buttons. These keyless technologies rely on radio signals. On some cars, grabbing the door handle will prompt the vehicle to send out a signal, unlocking the doors if the keys are near enough to intercept the radio waves. Others broadcast signals so they can unlock without any driver intervention, and keyless door locks are becoming increasingly common. Some cars have keyless entry for the boot, as well – a sensor underneath the car's bumper will automatically open the boot if you wave your foot around and the keyless fob is nearby. The fanciest motors now have digital keys, so you can unlock your car with your smartphone rather than the keyless fob. These systems use a combination of Bluetooth, near-field communication and ultra-wideband wireless connectivity.**

Winston Churchill and several European royals all owned Scripps-Booth cars

### A LONG ROAD

**Central locking first appeared in 1914 on a luxury roadster built in Detroit by Scripps-Booth. That vehicle innovated beyond car locks, too, with the first spare tyre. Scripps-Booth sold each car for $775 (£568) – equivalent to $21,607 (£15,849) today. Central locking didn't catch on straight away, however. The technology reappeared on the 1956 model of the Packard Clipper, which launched in Detroit. The rest of the world had to wait until 1982 for remote central locking, when the Renault Fuego broke Detroit's innovative stranglehold.**

**DID YOU KNOW?** In 1914, car locks weren't needed on most cars because they were often missing doors, windows or tops




# OPEN UP

**Central locking relies on a combination of mechanical hardware and electronics**

**1 CATCH AND RELEASE**
When you turn the key, that lifts a lever called a pawl, and that releases a catch.

**2 CHANNEL CREATION**
Once the pawl lifts, the catch rotates, creating a horizontal channel.

**3 STRIKING OPEN**
That horizontal channel enables the door striker to slide free from its latch, opening the door.

**4 MOTORING ALONG**
A small electric motor unlocks the rest of the doors simultaneously.

**5 ELECTRIC ADDITIONS**
Most modern cars combine smaller, lighter and more versatile electric systems with lock and striker mechanisms.

**6 DRIVING THE TECH**
An electric motor inside the driver's door helps release the locking mechanism from the striker plate.

**7 GEAR SHIFT**
The motor works alongside a conventional gear to ensure movement is smooth.

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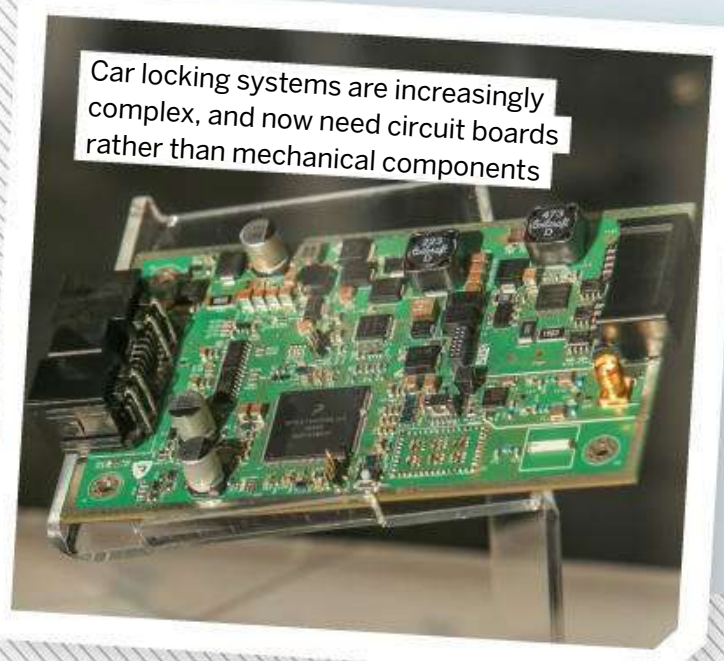

Car locking systems are increasingly complex, and now need circuit boards rather than mechanical components

**"The first car with this innovation appeared way back in 1914"**

© Alamy / Getty

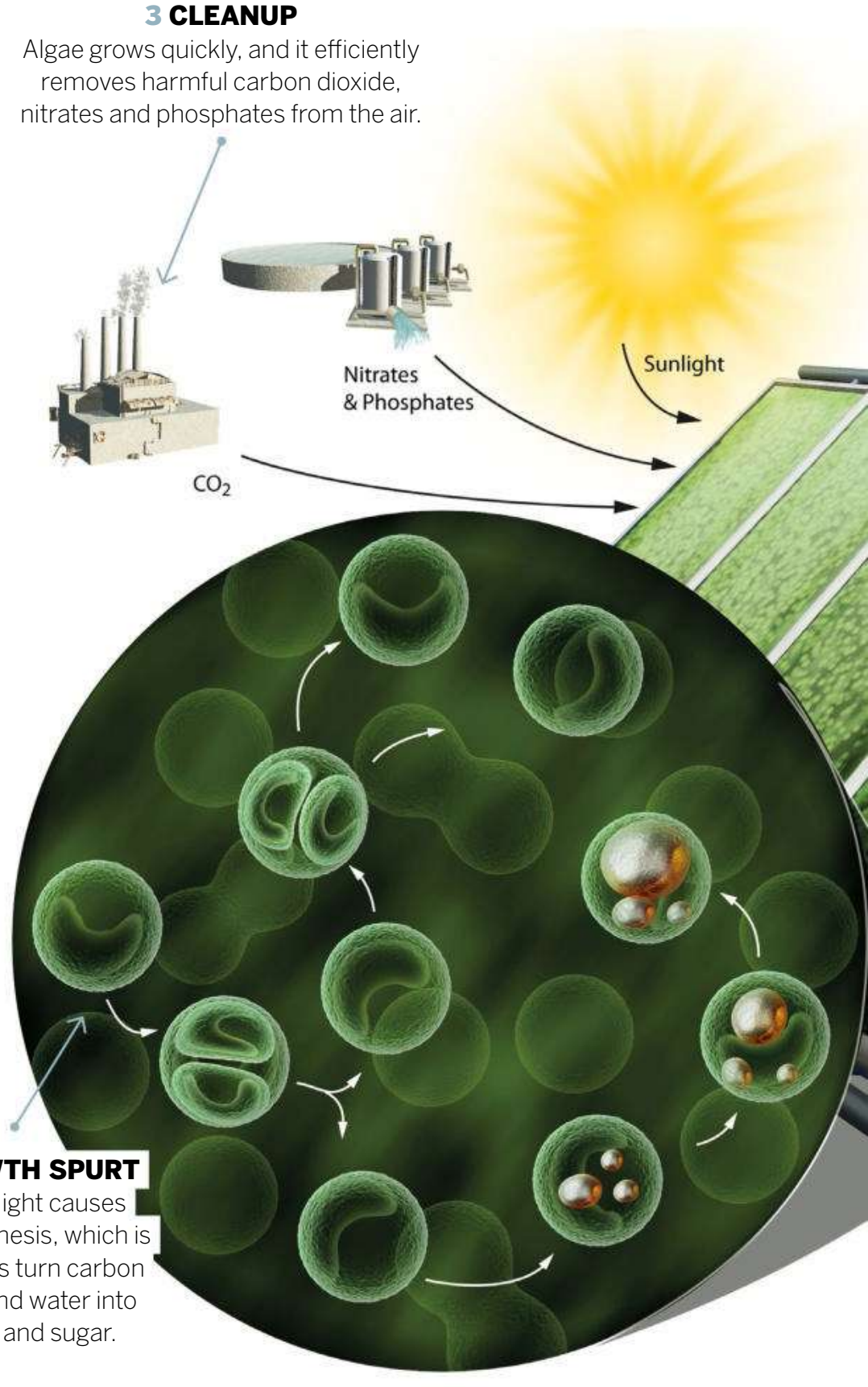
TRANSPORT

85 per cent of liquid biofuel that's produced globally uses ethanol

# WHAT IS BIOFUEL?

Biofuels are futuristic fuels that can power cars and trucks with crops, algae and even rubbish. Here's how they're produced

WORDS **MIKE JENNINGS**




Wheat and maize are used to make bread, pizza and other delicious foods, but in a few years they could also power your car. Renewable biofuels could soon replace the harmful fossil fuels that we're used to using. It's now well-established that fossil fuels are incredibly harmful to our health and the environment, and they're not renewable, either. When so many people rely on petrol and diesel to power vehicles, it makes sense to develop a renewable alternative that's easy to use.

That's where biofuel comes in. The most common biofuel produced globally is ethanol, and it's used frequently in Brazil and the US, while biodiesel is more popular in Europe. Ethanol is a clear, flavourless alcohol that's created by fermenting and distilling sugary crops like wheat, corn and sugar cane. It's combined with petrol to make fuel more environmentally friendly, and it's already in widespread use. More than 95 per cent of petrol sold in the US contains ethanol, and E10 fuel – made from ten per cent ethanol – is now the standard petrol in the UK. Alcohol combines with oil or fat to create biodiesel. It works directly in many car engines, but it's usually combined with conventional diesel to create a more effective blend. It's produced from vegetable oil, animal fat, soy or palm oil.

There's a huge amount of potential in biofuel, and most of the big energy companies have already invested – but emerging energy sources like ethanol are first-generation biofuels, and they've got issues that need fixing before they can go mainstream. It currently takes more ethanol than gasoline to produce the same amount of energy, for instance. Production is expensive, and several parts of the process sometimes use fossil fuels, which means that some biofuels aren't actually carbon neutral.

**Did you know?**

**Brazil and the US produce 87 per cent of the world's ethanol**

Some environmental campaigners also say that it would be more useful to grow crops for food rather than biofuel, and that growing crops for biofuel can cause problems with soil erosion and deforestation. Using land for fuel rather than food can lead to an increase in food prices, too, and can hinder natural habitats. Crop and fat-based biofuels may not be perfect, but those aren't the only biofuels available – some organisations are creating biofuels with algae instead. This process uses water and land that often isn't suitable for many other situations, so it doesn't take up space that's useful for food production, and it often has better yields than other types of biofuel components.

There's plenty of development beyond algae, too. Many companies are developing crops specially for biofuels, and those will improve yields, increase efficiency and reduce costs.

**DID YOU KNOW?** Biofuel has been around for decades; Ford's Model T, which launched in 1908, ran on ethanol as well as petrol

# THE ALGAE ALTERNATIVE

**Algae is touted as a more efficient option for biofuel creation – but how does this work?**

**1 SPECIALIST FACILITIES**
Algae for fuel production is usually grown in a nutrient-rich water system called a bioreactor that's exposed to sunlight.

**4 WATER MESS**
Once algae is harvested, it's usually dehydrated. After that, oil and carbohydrates can be used to create biodiesel or ethanol.

Extraction

**5 SURFACE PRESSURE**
Alternative methods involve subjecting algae to high-pressure and temperature environments to extract oil to use in biofuels.

Some even use seaweed. Scientists are also working on schemes that will be able to extract biofuels from household waste, wood chips and other junk – a move that could massively increase the material that's viable for biofuel production. These second-generation biofuels could make biofuel far cheaper and more accessible, and help cut emissions down.

## SWEET REACTIONS

**Creating ethanol is a complex chemical process. Plant cells contain cellulose, hemicellulose and lignin. Acids, enzymes and other chemicals break the plants down, and the result is a pure sugar solution called sucrose. At this point, scientists add yeast, and the solution heats to between 250 and 300 degrees Celsius. The yeast has an enzyme called invertase. Heat activates this, converting the sucrose into glucose and fructose. These sugars combine with another enzyme, called zymase, which converts them into ethanol. That ethanol still has lots of water, though, so the next step involves boiling. Because ethanol boils at 78.3 and water boils at 100 degrees Celsius, the ethanol boils and turns into vapour first; it can be separated from the water, condensed back to liquid form and used for biofuel.**

Biofuel can increase the lifetime of your car's engine

**"Wheat and maize could power your car in a few years"**

## RACING AHEAD

**The World Rally Championship (WRC) is a global motorsport competition that made a groundbreaking switch to biofuel for its 2022 season. The WRC now uses a second-generation biofuel made from organic waste material, which is combined with synthetic fuel. The production process uses renewable energy and takes carbon dioxide out of the atmosphere thanks to carbon capture. It's the first time that a fossil-free fuel has powered a world motorsport championship. This isn't the only time you'll see biofuel used in a high-performance situation, either. Formula 1 now runs with a ten per cent biofuel blend, and the aviation and shipping industries are increasing their usage. It's even being used by space start-ups.**

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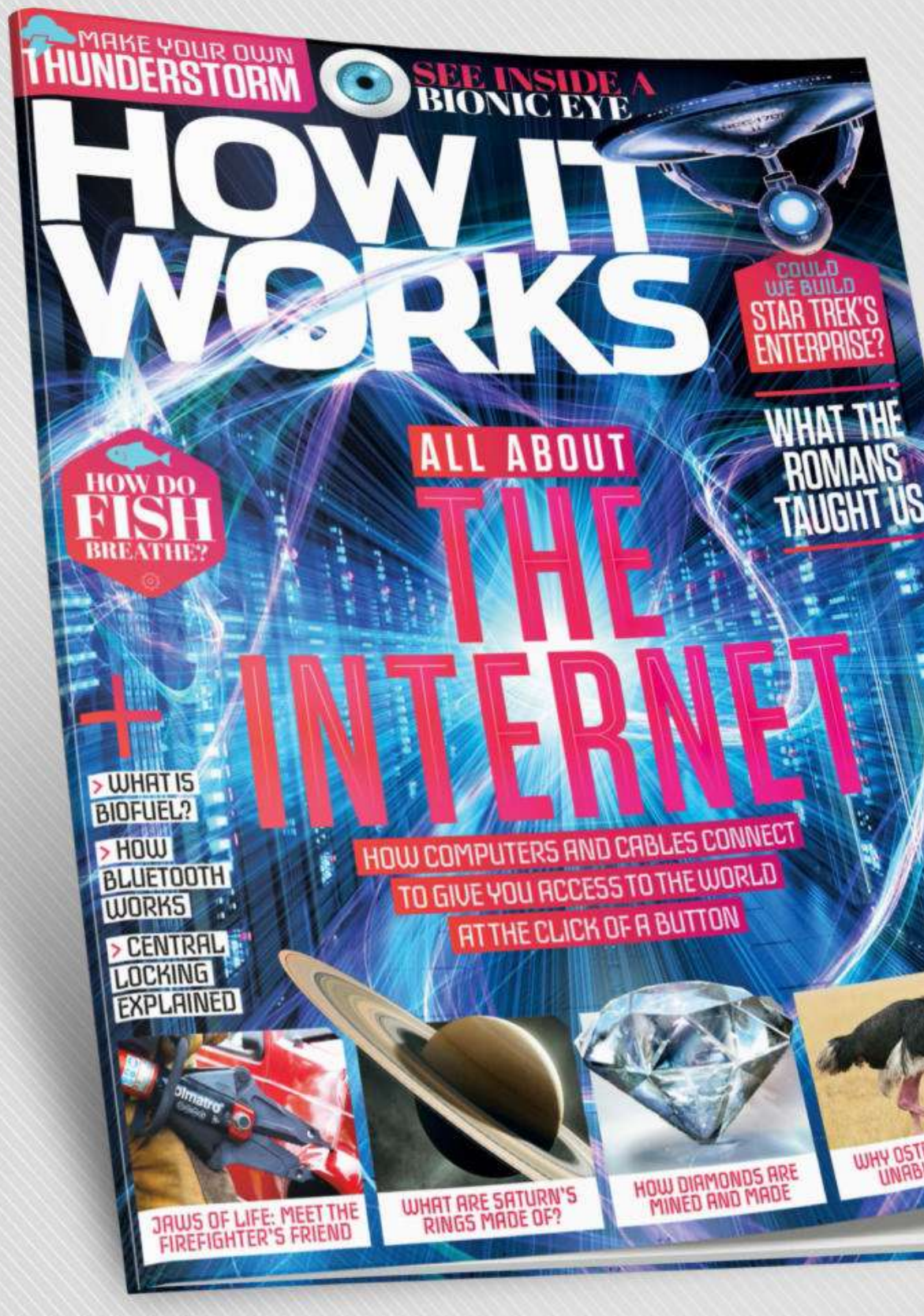

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Fulgurite is formed from sand or other sediment fused by lightning

**Did you know?**

Lake Maracaibo has lightning 300 nights a year

# Can glass be made from lightning hitting sand?

**Gwyneth Barton**

This is indeed possible, as glass and sand are both made from the same chemical: silicon dioxide. Silicon dioxide has an extremely high melting point, so first the sand has to be heated past this for it to become a liquid. In sand the silicon and oxygen atoms are arranged in a very orderly way. When sand is heated to very high temperatures, this arrangement breaks down and the position of the atoms becomes disorderly and random.

If the sand is cooled quick enough then the atoms of oxygen and silicone don't have enough time to revert back to their nice orderly arrangement so they form the substance we know as glass.

When lightning occurs, the strike point can reach temperatures of up to 30,000 degrees Celsius, which is much hotter than the surface of the Sun. Providing the sand is of the right kind, it's possible that glass will form. Fulgurite is the term given to what is left over, which is a hollow glass tube, and a strike can sometimes penetrate up to 15 metres below the surface of the sand. The type of sand the lightning strikes is a major factor as to whether it will turn into glass or not. Meteorite impacts have also been known to release a large enough amount of energy to convert sand into glass.

Due to the unpredictable nature of lightning strikes, and given that they can be highly dangerous, it might be a risky business opportunity in more than just the financial sense. On average there can be more than 100 lightning strikes happening every second across the globe, but the chances of these being over the right type of sand at exactly the right moment are very low, so don't get your hopes up!

## WHY DO SKUNKS SMELL?

**Susie Green**

Skunks are renowned for their ability to smell really bad. Not something you want to have associated with your species, but for skunks it's a massive advantage. Skunks do this by spraying a chemical, or thiol, which is made of sulphurous compounds, and they have a very strong odour. Not only that, but these thiols are very good at sticking to materials and mixing with chemicals to make the smell stick. If a skunk has sprayed this on any of your upholstery or clothes, the smell can often last for weeks. In fact, scientists have successfully isolated the compounds that make the smell stick and applied it to perfumes and fragrances in order to give a longer lasting smell.

A skunk will only spray if it's agitated or stressed, and releases the spray from scent glands in the anus. In addition to smelling awful, the spray can cause vomiting and have effects similar to tear gas, which is a great defence mechanism. As an interesting side note, skunk spray is also phosphorescent, so it will glow in the dark.

## Is it possible to knock Earth out of its orbit?

**Dan Combes**

The impact required would be so large that Earth would likely be destroyed. Many astronomers think that around 4.5 billion years ago, when the Solar System was forming, Earth got a 'big whack', which resulted in our Moon. At this stage in the Solar System's evolution, both bodies would have been made mainly of molten material that had not yet solidified. Their iron-rich cores merged, while parts of their outer layers were vaporised and thrown into orbit around Earth. This material coalesced to form our rocky Moon. Earth gained angular momentum, and its orbit may have changed, although only slightly. This impact is likely to have been 100 million times bigger than the impact that wiped out the dinosaurs. If a body that size hit today's mostly solid Earth, we would be blasted to smithereens.

Not all mushrooms are safe to eat

## How do you tell if a mushroom is poisonous?

**Zaki Hassan**

There are many different types of mushroom, so without getting a good grasp of individual kinds of mushroom it would be difficult to say whether one is poisonous or not. A general rule would be to never consume a mushroom unless you have a positive identification.

Some deadly varieties of mushroom include the death cap, destroying angel, *Galerina* species, small *Lepiota* species and the deadly webcap, and to be able to detect these you would need to have observed them all at different stages in their development. Having knowledge of where the mushroom has come from can help, too, as some mushrooms that are safe in Europe have deadly lookalikes in North America.

It's wise to avoid old wives' tales such as 'a mushroom is poisonous if it tarnishes silverware or turns blue when bruised', as these are both completely false statements. The truth of the matter is that there are no external easy-to-identify characteristics that all poisonous mushrooms have in common. To be absolutely safe, unless you are an expert mushroom identifier or mycologist, we would advise buying your mushrooms from a reliable source such as supermarkets, grocers or restaurants.

© NASA / Getty

# BRAINDUMP

## WHY DOES MINT TASTE 'COLD'?

**Anthony Miller**

We've all experienced the 'cool' sensation induced by eating a mint at some time or another, and the reason why this happens is due to an active ingredient called menthol. When we perceive something to be hot or cold, this is due to electrical signals from the nerves which come into contact with the hot or cold 'thing'. Our brain then interprets these electrical signals as instructions.

Mints usually contain an active ingredient called menthol. Menthol has the ability to affect the pores on our nerve cells, which changes the electrical activity of the cell. This change in electrical activity corresponds to the same change that would take place if something cold came into contact with the cell. The cell interprets the change in activity due to menthol as a change in temperature and sends that information to the brain.

Is it the weather or the sweets?

**Did you know?**
A sneeze's max velocity is ten miles per hour

Mice aren't always responsible for holes

## How do the holes get in Swiss cheese?

**James Butler**

To make cheese you need the help of bacteria. There are various types of bacteria used for making Swiss cheese; the one responsible for the holes is called *Propionibacterium shermanii*. Once this bacteria is heated slightly, it reacts, forming bubbles of carbon dioxide, which become the final holes in the product. The technical term for these holes is 'eyes'. The size of these 'eyes' can be controlled by the cheesemakers by altering the acidity, temperature and curing time of the mixture. Generally, in most foods which require fermentation, bubbles of carbon dioxide will be formed, but most of the time they escape. The procedure of making Swiss cheese means those bubbles remain trapped inside, which means there will be 'eyes' in the final product.

## HOW DOES THE SPEEDOMETER IN AN AEROPLANE WORK?

**David Carter**

Airspeed is a measurement of the plane's speed relative to the air around it. On the aircraft there's a tube called the pitot tube. The open end of the pitot tube is usually mounted on a wing and faces towards the flow of air. An airspeed indicator measures the difference between a static sensor inside the plane and a sensor in the air stream. The rush of air in flight causes a pressure differential between the static tube and the pitot tube. This makes the pointer on the airspeed indicator move. An increase of airspeed leads to the pressure at the end of the pitot tube rising. The air pressure pushes against a diaphragm that moves a connected mechanical pointer on the face of the indicator. The indicator is calibrated to compensate for winds in the air using electronic readouts from the air and ground. This also compensates for altitude and air temperature.

A pilot has a lot to monitor

## WHY DO WE HICCUP?

**Steph McDowell**

There are over 100 physiological reasons as to what sets hiccups off, the most common being expansion of the stomach and movement of stomach acid into the oesophagus. After this then it could be an irritation of the thorax or the phrenic nerve.

The mechanism of a hiccup usually involves a strong contraction of the diaphragm, the neck muscles and some other surrounding muscles. Just after the contraction begins, we start to inhale, at which point the glottis opening shuts off the windpipe, producing the 'hic' noise.

Scientists are still trying to find the actual purpose of hiccups. One theory is that they may have served useful for a common ancestor of ours. Standing on two legs gives us the advantage of using gravity to help digest our food, whereas four-legged creatures have to digest horizontally, meaning it's easier for food to get stuck in their throats. Some scientists think the lodged food could have hit a nerve responsible for triggering the hiccup, allowing the food to be swallowed. If this is the case then hiccups could have been highly useful.

# Why do sharks go into a tonic state when flipped over?

**Carol Johnson**

Many animals are capable of entering a trance-like state called tonic immobility, whereby they appear dead to their surroundings. In the case of sharks, it has been observed in many different species, such as the lemon shark, reef shark and tiger shark, upon simply placing them upside down.

During tonic immobility the dorsal fin becomes straightened and the breathing and muscle contractions become more relaxed. It's such a reliable behaviour in certain sharks that it's used as a type of anaesthesia before minor surgery.

Some killer whales have learned to take advantage of this by using their tails to create currents in the water that can turn a shark over in order to eat it. The reason this happens to sharks is unclear, but it can be argued that tonic immobility has a role to play in survival, allowing the shark to blend into the surroundings by being completely motionless, but in this case it's obviously a disadvantage for the shark.

It has also been speculated that it may be something to do with the mating ritual of certain shark species, as in some cases it can be induced by massage.

## WHAT'S A NAUTICAL MILE?

**Hayley Horrocks**

A nautical mile is based on the circumference of the Earth. If you cut the Earth in half at the equator, picked up one of the halves and looked at the equator as a circle, you could divide that circle into 360 degrees, then divide a degree into 60 minutes. A minute of arc on Earth is one nautical mile. Because this takes into account the arc of the Earth, it's used in air and sea travel. A nautical mile is 1,852 metres, 1.852 kilometres, 1.1508 miles or 6,076 feet. The nautical mile is used by sea and air navigators because of its convenience when working with charts and maps. Most nautical charts are constructed on a scale that varies from the equator to 80 degrees north or south latitude. This means it's difficult to show a single linear scale for use on charts, realistically on scales smaller than about 1/80,000.

This isn't practical for more accurate navigation using lower scale charts. Since a nautical mile equals a minute of latitude, it's easy to measure a distance on a chart with dividers using the latitude scale on the side of the chart directly to the east or west of the distance being measured. Being used to working with miles and kilometres means that this sounds complicated, but for the purpose of working with charts and maps it's far easier for navigators to use.

Sailors use nautical miles to navigate

© Getty

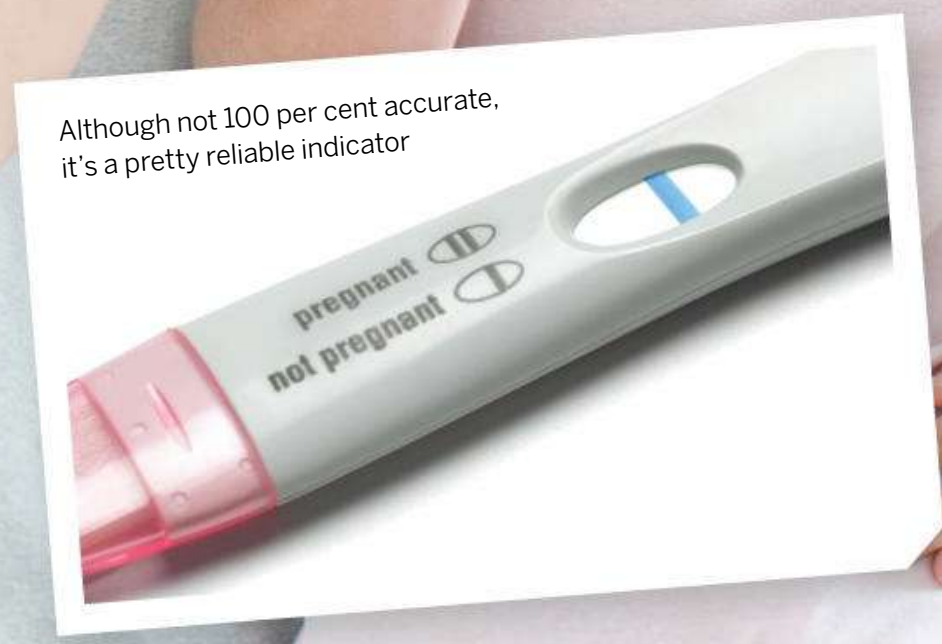
# How does a home pregnancy test work?

Sally Bright

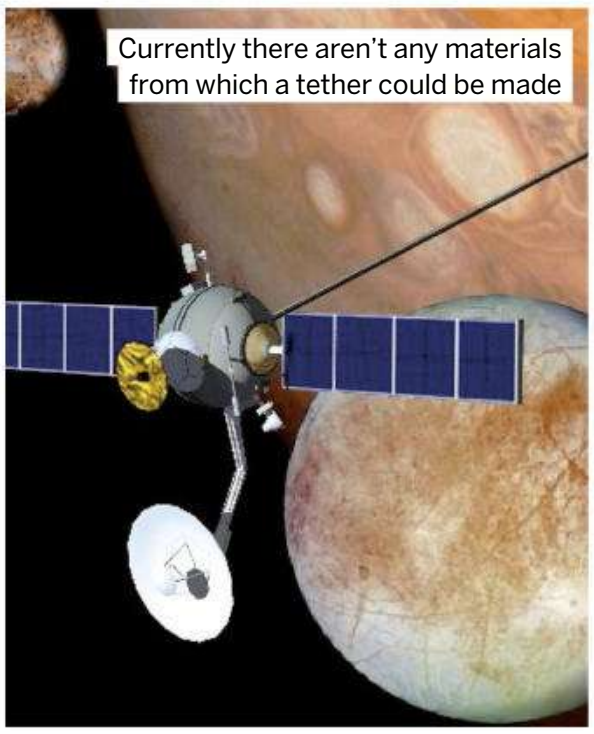
Home pregnancy tests work by detecting a hormone called human chorionic gonadotropin (hCG) in urine. hGC is only produced by pregnant people, therefore any amount of hCG detected in a person's urine will mean they are expecting a baby. hCG is produced by cells in the uterus and is responsible for signalling the ovaries to produce oestrogen and progesterone to help the foetus grow. hGC can be found in the urine or blood, and levels of hGC increase as pregnancy progresses. Very sensitive home pregnancy tests can detect hCG as early as nine to ten days after ovulation.

The detection of hCG is carried out by human-made proteins called monoclonal antibodies. They basically bond with the hCG upon detection, which creates a distinct colour change in the test. The colour produced will vary in intensity based on how much hCG is in the urine.

When you take a home pregnancy test, you need to soak part of the test in your urine. Most home pregnancy tests have two lines: one is the control line and should stay the same regardless of whether you are pregnant or not. This line or symbol shows whether the test is working properly. If the control indicator doesn't appear, the test is not working properly and you should not rely on the results.



Although not 100 per cent accurate, it's a pretty reliable indicator


Currently there aren't any materials from which a tether could be made

## HOW WOULD A SPACE TETHER BE BUILT IF WE HAD THE MATERIALS TO BUILD IT?

Mohammed Al Hajji

There have been many different attempts to devise a way to build a space tether, or 'elevator', and most involve constructing a really long cable of some kind. The idea is that the cable would be in a geostationary orbit around Earth; one end of the cable would be attached to either a fixed or mobile platform on Earth and the other would connect with some kind of counterweight high above the Earth's atmosphere.

The main technical issue in building such a cable is to keep it from collapsing under its own weight. One idea is to vary the thickness of the cable to allow for the tension to stay constant throughout, as the gravitational force on the cable increases the closer it is to Earth.

It would need to be built out of an incredibly strong yet very light material. Currently there are no such materials which could handle this strain. However, there is a lot of exciting research happening at the moment in the field of carbon nanotubes which may prove useful. Carbon nanotubes are extremely strong carbon structures which have been synthesised in laboratories, and it's been theorised that these nanotubes may have what it takes to withstand the strain while still being a relatively light material.

## WHY USE SALT TO MELT ICE ON THE ROADS?

**James Hendy**

Salt lowers the freezing and melting point of water and ice. The melting point of ice under normal conditions is zero degrees Celsius. Seawater, however, freezes or melts at -2.2 degrees Celsius due to its high salinity.

As to why salt lowers the melting and freezing point of water, this is a bit more difficult to explain without going into some complex chemistry. Water is made from $H_2O$, and anything else which gets in there, such as sodium in the case of salt, gets in the way and makes it harder for the $H_2O$ to bond as ice.

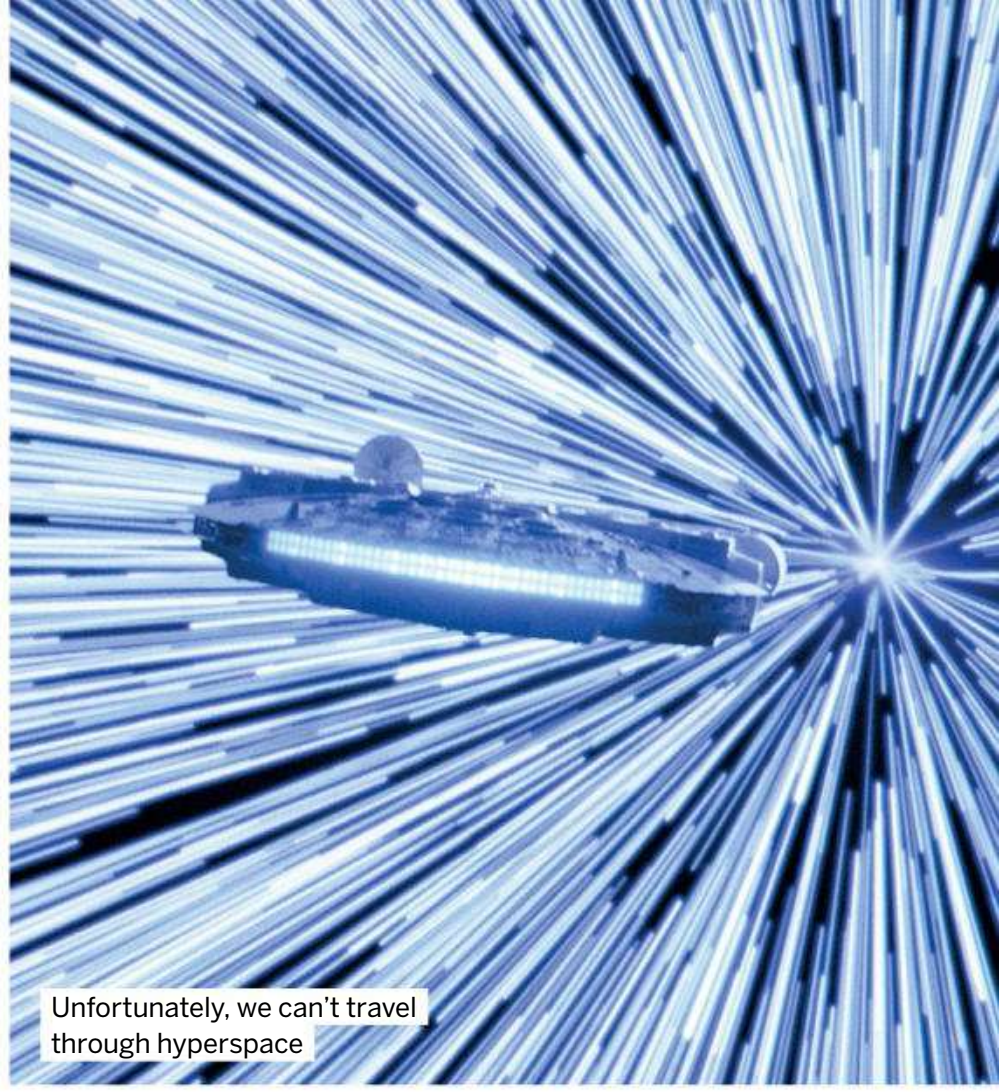
Upon sprinkling salt onto ice, the salt first dissolves into the liquid water surrounding the ice, causing the ice to melt. The salt can only lower the melting and freezing point of water up to around -16 degrees Celsius. If the temperature is below this point then salt is rendered ineffective, and it would be better to pour sand over the ice to help increase traction.

## COULD WE TRAVEL FASTER THAN THE SPEED OF LIGHT?

**Stuart Selwhort**

The speed of light is roughly 300,000,000 metres per second, which is fast enough to travel around our planet seven-and-a-half times a second – that's fast! In fact, it's the fastest thing we know of, but why is it so difficult to travel at this speed? Surely if we were far away from any other forces, like gravity, we could just keep accelerating and eventually we would get there, wouldn't we?

Unfortunately, no. One of the things that Einstein realised from his theories of relativity is that as any particle of mass increases in speed, it also increases in mass. By the time the mass has finally reached the speed of light, it would have infinite mass, which would mean to get it to that stage would have required an infinite amount of energy.



Unfortunately, we can't travel through hyperspace

## HOW DO CIGARETTE FILTERS WORK?

**Ellie Johnson**

Filters were added to cigarettes in the 1950s when it was discovered that smoking causes lung cancer, leaving cigarette manufacturers under pressure to convince people that smoking was safe. Filters are made of a synthetic fibrous mass called cellulose acetate, which is a kind of fine plastic packed tightly so that it looks like cotton wool.

The material is designed to accumulate the vapours and tar in the fibres before they reach the smoker's mouth. However, filters in no way lessen the unhealthy smoke being inhaled. In fact, chemicals are added to make cigarettes taste better and to increase the speed at which nicotine is delivered to the brain, thereby keeping users hooked.

Filters aren't able to stop all the chemicals from entering your body

Dreams can be easily forgotten upon waking

## Why do we sometimes remember our dreams, but sometimes not?

**John Harrold**

We're afraid this is a question for which there's no satisfactory answer based on our current understanding of the brain. One thing studies have told us is that dreams seem to happen more vividly and frequently during the REM (rapid eye movement) stage of the sleep cycle, which tends to occur roughly four to five times in a normal night's sleep.

It's been reported by several studies that you are much more likely to remember the dream you were having if you are woken in the middle of this REM cycle. If you would like to remember your dreams more frequently, you could try setting your alarm clock to go off in the middle of your REM sleep cycle – likely to be near the end of your night's sleep – and write down what you remember.

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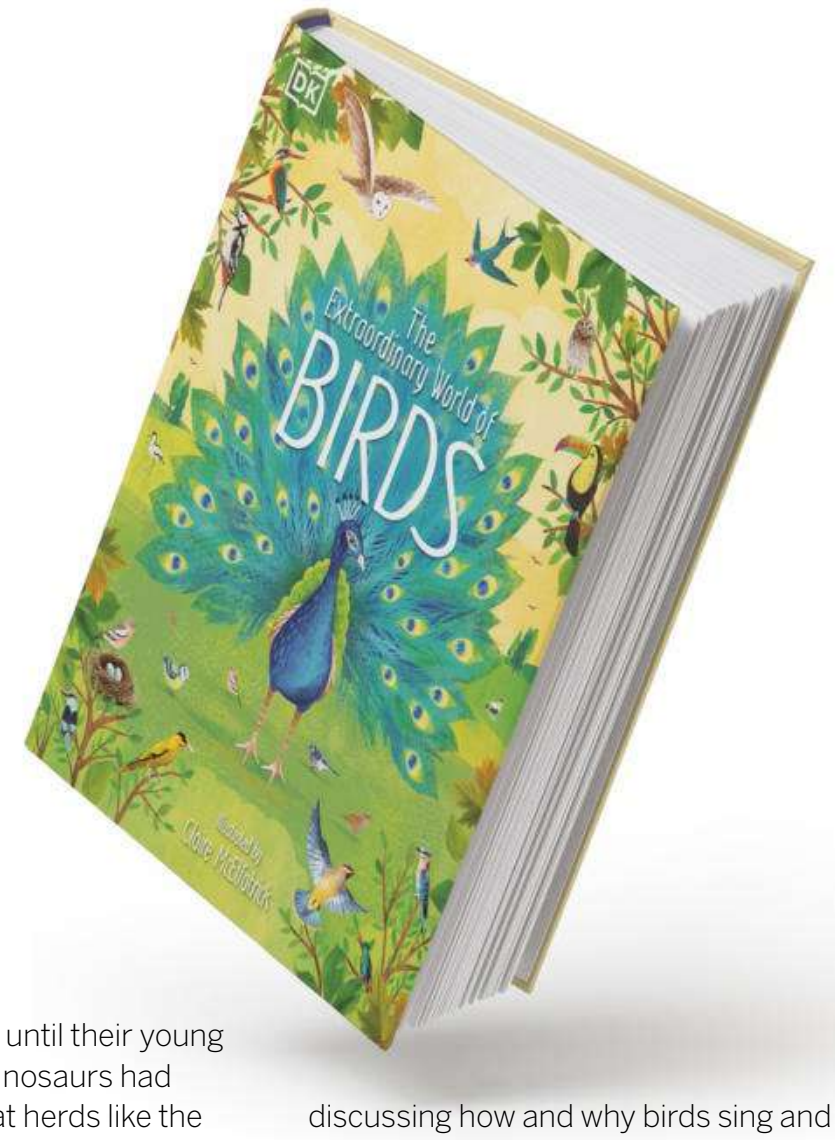


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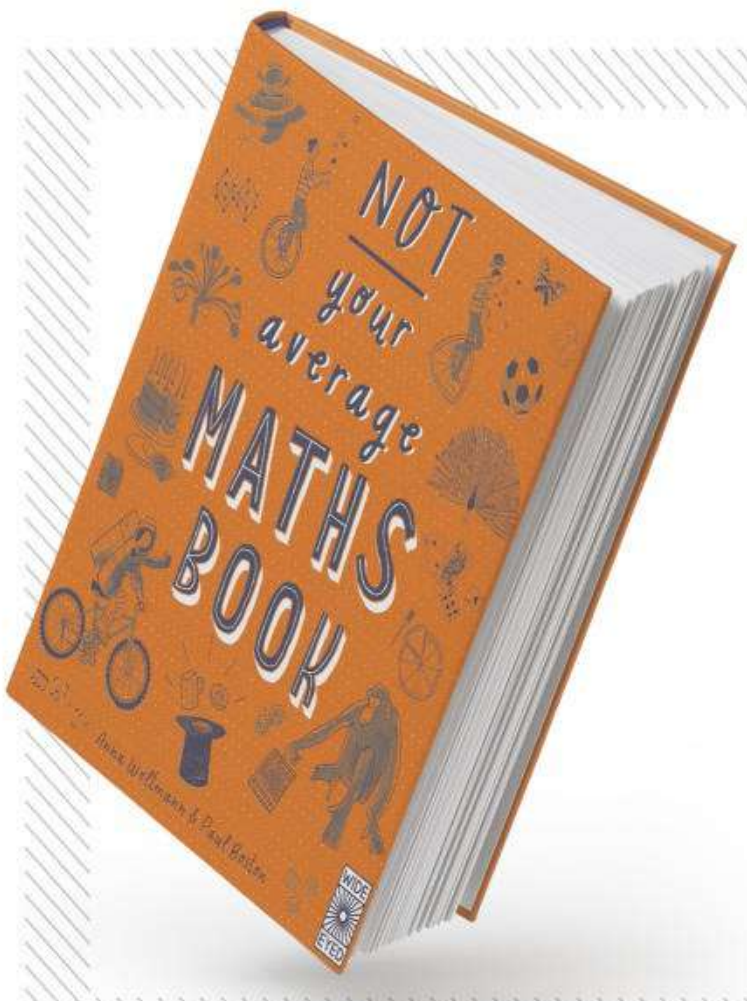
If you know nothing about the evolutionary origins of modern birds, then the following could be considered a bit of a spoiler for David Lindo's *The Extraordinary Life of Birds*: they evolved from dinosaurs. Every single species of bird you see today, from tiny finches and hummingbirds to huge ostriches, soaring eagles, chickens and penguins, are descended from a group of dinosaurs called theropods, which included the *Tyrannosaurus rex*.

It's a mind-blowing fact to open this book to for anyone who had no idea about it, and it really sets the tone for the rest of *The Extraordinary Life of Birds* because after that, you can't help but compare what you know about dinosaurs to the detailed information on the lives of birds from around the world. Both dinosaurs and birds laid eggs that they had to incubate until their young hatched, for example. Some dinosaurs had feathers, many roamed in great herds like the flocks of birds you see today and some birds even look like they could have been plucked from a prehistoric era. If you've ever encountered a cassowary or an emu in a zoo, or have been lucky enough to get close to the likes of a golden eagle, you'll know what we mean.

Lindo walks us through the different behaviours of birds from across the world,

**Lindo walks us through the different behaviours of birds from across the world**

discussing how and why birds sing and flock, how they fly and, in the case of a handful of bird species, why they can't fly. He also delves into peculiar characteristics of specific species, like the crowned sandgrouse, which lives in dry desert conditions and avoids areas with plants where predators lie in wait. Or the herring gull, which dive bombs intruders that stray close to its nest, and given the chance will poop on them. Accompanied throughout by Claire McElfatrick's wonderfully detailed illustrations, *The Extraordinary Life of Birds* signs off with a guide to how you can help wild birds in your garden or local park. It's a great way to introduce budding ornithologists to what could be a lifelong interest in our feathered friends.

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As far as telling the story of the evolution of life on Earth and how the universe came to be, *Gaia and Luna* is a book that takes a whole new approach. In a cross between fiction and fact, Mark Newton uses the Earth (Gaia), Moon (Luna) and the other celestial bodies in our Solar System as sentient characters to narrate the story.

The book begins after the creation of the Solar System and its planets, when Gaia discovers that something new has sprouted on her: life. What follows is essentially the story of humankind, our biological and societal evolution and our many shortcomings as a species.

This charming book offers a new and interesting approach to telling the story of life on Earth, although it's not clear who it's trying to tell the story to. It sounds more suitable for a younger audience, but its content and long-form format are better suited to a more mature reader. Nevertheless, *Gaia and Luna* is an

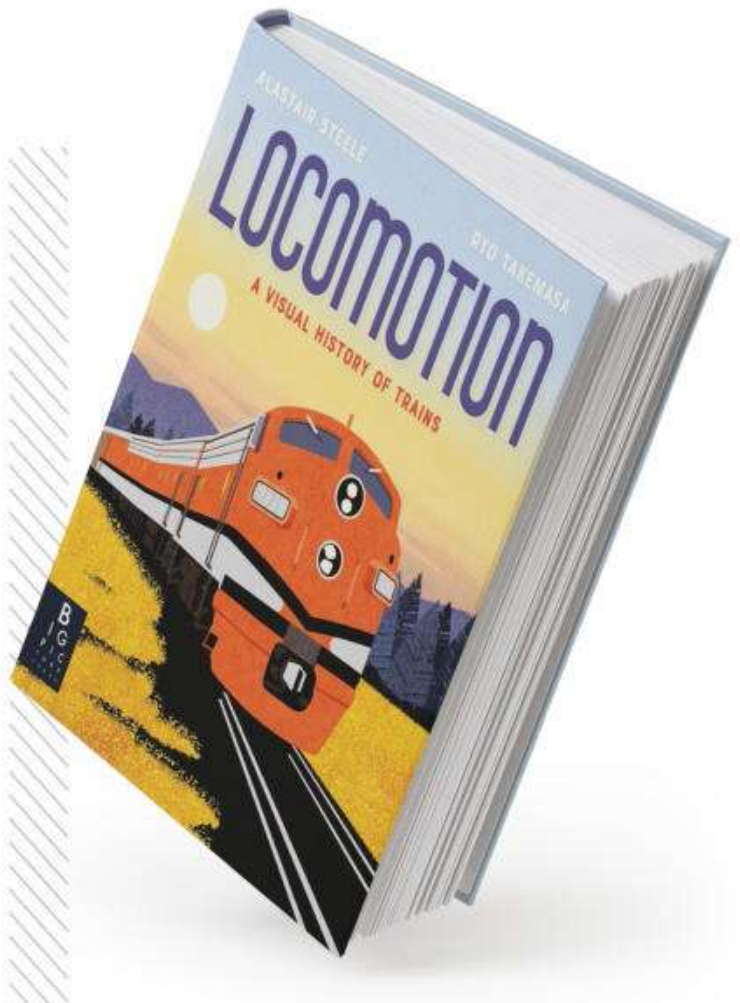
# ALEXANDER VON HUMBOLDT

## THE LIFE STORY OF A CLIMATE GENIUS

AUTHOR **PETER NYS**
ILLUSTRATOR **CONZ**
PUBLISHER **CLAVIS PUBLISHING**
PRICE **£12.99 / $16.95**
RELEASE **7 APRIL**

Alexander von Humboldt wasn't just a famous scientist. He was also a mining engineer, explorer, geologist, inventor, surveyor, mathematician, tour guide, linguist, author, illustrator, human rights activist and many other skilled vocations that normally take a single lifetime of dedication. In this book, the most interesting elements of his life are presented alongside informative and immersive illustrations to inspire the minds of children aged nine and above.

Discover how von Humboldt explored the world in the 1700s, researching earthquakes, discovering the cause of changing water levels and illustrating his findings of different climatic zones. The book perfectly demonstrates how inaccurate some historic views about the climate were when largely based on guesswork and the importance of scientific research in uncovering the facts. As an early climate activist, von Humboldt warned of the dangers of issues such as factory pollution and deforestation. Every page of this book holds inspiration to learn, care and explore more about the world around us.




# LOCOMOTION

## A VISUAL HISTORY OF TRAINS

AUTHOR **ALASTAIR STEELE**
ILLUSTRATOR **RYO TAKEMASA**
PUBLISHER **TEMPLAR PUBLISHING**
PRICE **£16.99 (APPROX. $22.85)**
RELEASE **3 MARCH**

For anyone with an interest in trains, this visual guide provides a detailed journey from the very first railways to the trains of the future. And while the visual elements alone are enough to give you a taste of how these vehicles have evolved, Alastair Steele's writing provides a full insight into the purpose, use and statistics behind each transition. In *Locomotion* you will find out how wartime operations shaped today's railways, learn how modern tracks have evolved to account for earthquakes and much more.

While this book contains no historic real-life photographs, the vibrant illustrations are a worthy replacement. Each one expertly portrays the dimensions, detailed features and time periods to give the reader an immersive experience across the ages. At the end of the timeline there's an illustrated overview of the full progression in rail travel. This allows the reader to see the changes together in one image and appreciate how far trains have come. To finish, a list of record breakers displays the world's most impressive and unusual trains and railways and where you can find them.

# BRAIN GYM

Give your brain a puzzle workout

## Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

**EASY**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2 | 4 | 8 | 6 | 7 | |
| 4 | 7 | | | 6 | | 1 | 2 | |
| | | | 9 | 7 | 1 | | 8 | 3 |
| | | | | 5 | | 9 | | 8 |
| | 5 | 4 | 8 | 3 | | | | |
| | 8 | | | 9 | | | 5 | 6 |
| | 2 | 7 | 6 | 1 | | | | 4 |
| | | 6 | | 2 | 9 | | 3 | |
| 1 | | 9 | | | 7 | | 6 | 2 |

**MEDIUM**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 | | | | 4 | | 9 | |
| | | 8 | | 5 | | | | 7 |
| | | 1 | | 6 | 8 | | 2 | |
| 1 | 3 | | 5 | | | | 4 | |
| | 9 | | 6 | 4 | | | | |
| 2 | | | 8 | 1 | | | | 6 |
| 7 | | | | 8 | | 2 | 6 | |
| | | 2 | 7 | | | 1 | 5 | |
| | 4 | | 1 | 3 | 2 | | | |

**HARD**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | | | |
| | | | | | 4 | | 1 | 7 |
| 8 | 2 | | 1 | 9 | | | | |
| | | 6 | | 5 | 7 | | 4 | |
| 9 | | | 8 | 6 | | 7 | | |
| 1 | | | | | | | 6 | |
| | | 2 | 7 | | | | | |
| 4 | | | | | | 2 | | 8 |
| | | 1 | 3 | | 6 | | | |

## Word search

Find the following words

BROADBAND
JAWS
DIAMOND
FISH
SATURN
EYE
INTERNET
ENTERPRISE
ROMAN
LOCK
BIOFUEL
BIRD

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J | A | Y | S | A | T | N | R | U | T | A | S | H | O | L |
| I | B | N | O | E | Y | A | N | T | E | P | R | S | I | E |
| F | R | O | J | E | H | S | I | N | T | R | E | O | N | K |
| L | O | C | K | E | W | C | K | B | I | D | N | R | T | B |
| Y | A | E | B | I | D | F | N | P | I | K | T | A | E | C |
| H | D | U | V | A | P | O | A | R | E | O | E | N | R | K |
| M | B | A | R | D | I | A | M | O | N | D | R | S | N | H |
| M | A | L | T | I | K | L | O | W | X | C | P | Y | E | Z |
| J | N | U | X | T | A | P | R | O | S | I | R | W | T | H |
| P | D | R | I | B | L | S | A | N | Y | E | I | U | T | P |
| B | R | Q | A | D | W | A | T | D | R | I | S | H | A | U |
| F | U | G | O | A | F | E | Y | E | W | I | E | S | P | M |
| B | U | P | J | I | N | G | P | L | E | A | L | I | O | Z |
| N | O | M | C | K | L | K | A | S | H | E | R | F | X | X |
| L | I | N | C | B | I | O | F | U | E | L | Z | E | L | D |

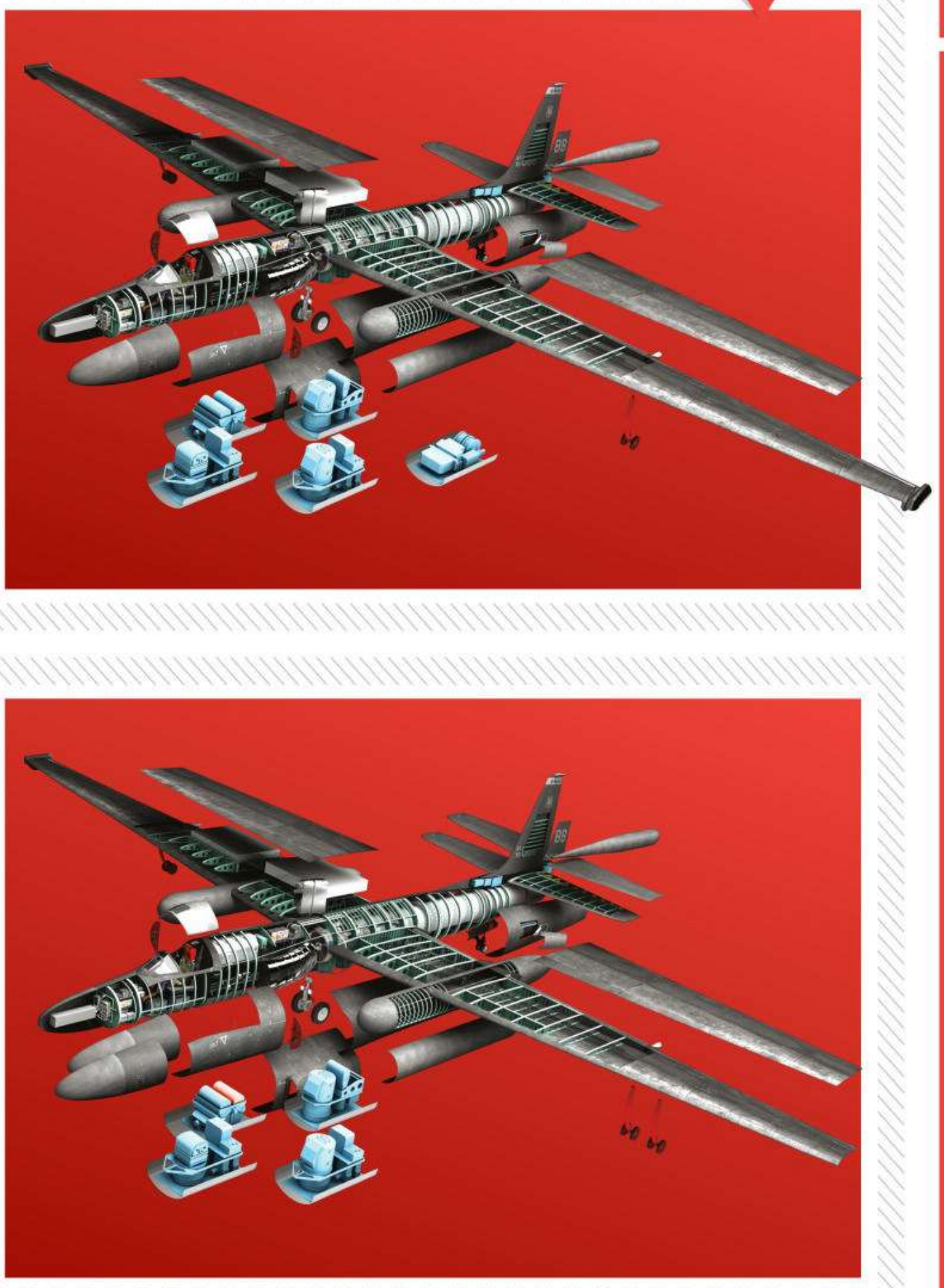
## What is it?

Hint: You could boil a kettle on this stuff

A

# Spot the difference

See if you can find all six changes between the images below





## Answers

Find the solutions to last issue's puzzle pages

**Q1** HYBRID
**Q2** BY ITS HEAD
**Q3** BLACK HOLE REGION
**Q4** WOOD
**Q5** RUBIDIUM
**Q6** WORLD WAR I

### What is it?

SPIDER

### Spot the difference

## QUICKFIRE QUESTIONS

**Q1 At what temperature are Celsius and Fahrenheit equal?**
- 32°
- 0°
- -40°
- -273.15°

**Q2 Which colour's wavelength is close to infrared radiation?**
- Violet
- Blue
- Green
- Red

**Q3 What marine mammals is also known as a sea cow?**
- Blue whale
- Manatee
- Hippopotamus
- Elephant seal

**Q4 Which of these planets is closest in size to Earth?**
- Venus
- Mars
- Neptune
- Mercury

**Q5 Which car manufacturer also makes aeroplane engines?**
- Citroën
- Škoda
- Fiat
- Rolls-Royce

**Q6 Which of these was not invented in ancient China?**
- Earthquake monitor
- Magnetic compass
- Gunpowder
- Bicycle

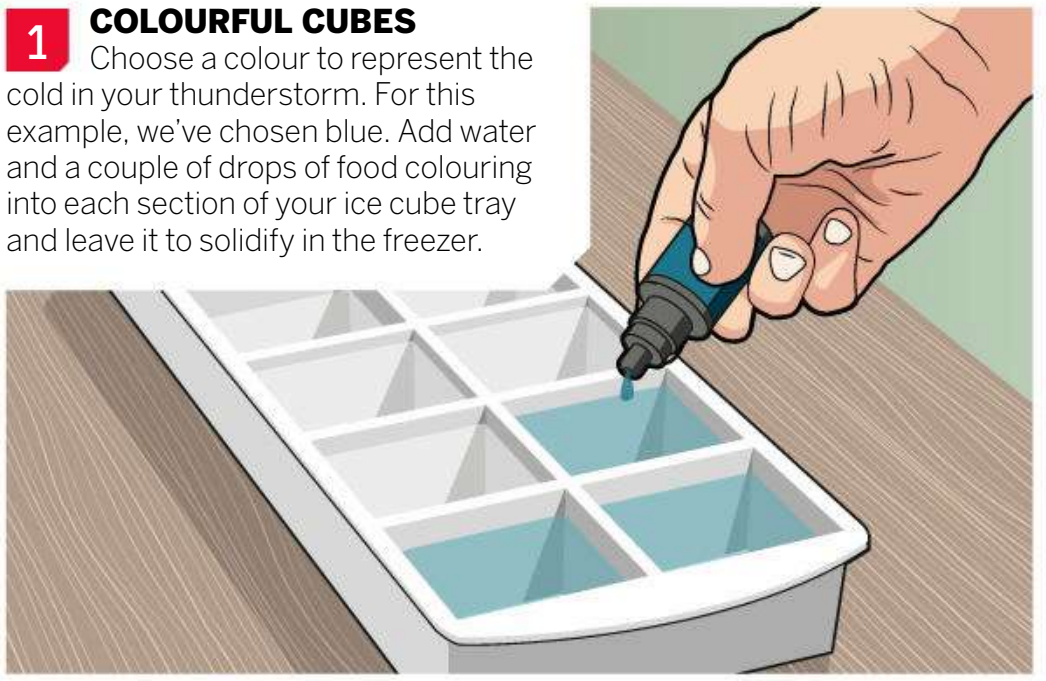
© Getty

# MAKE A THUNDERSTORM IN A TANK

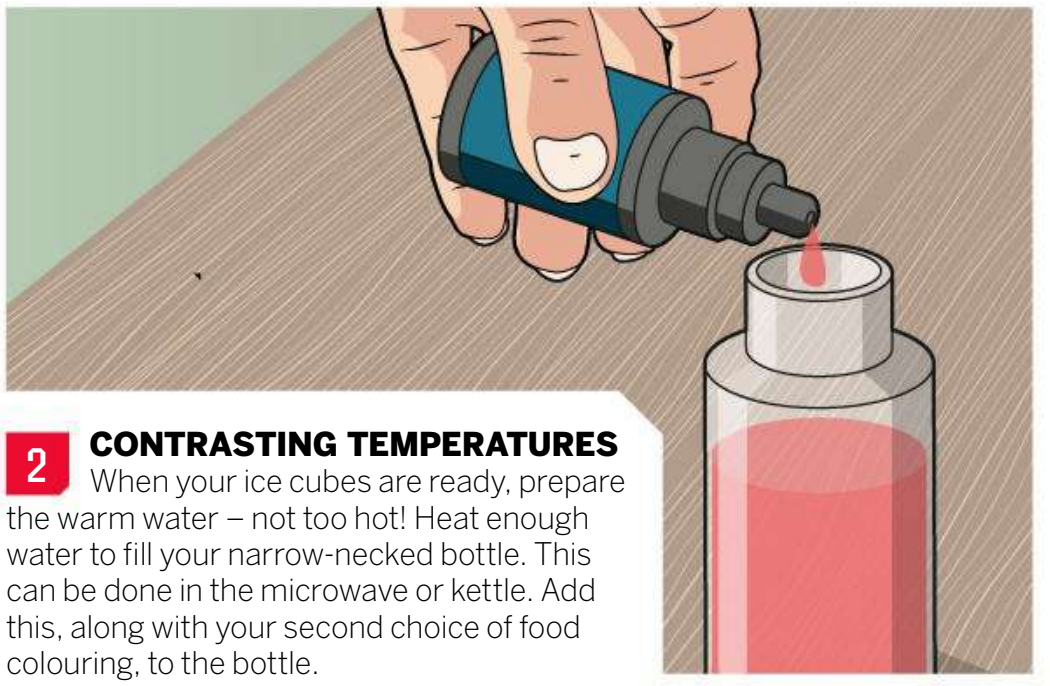
Create this mesmerising visualisation of a turbulent sky

**KIT LIST**

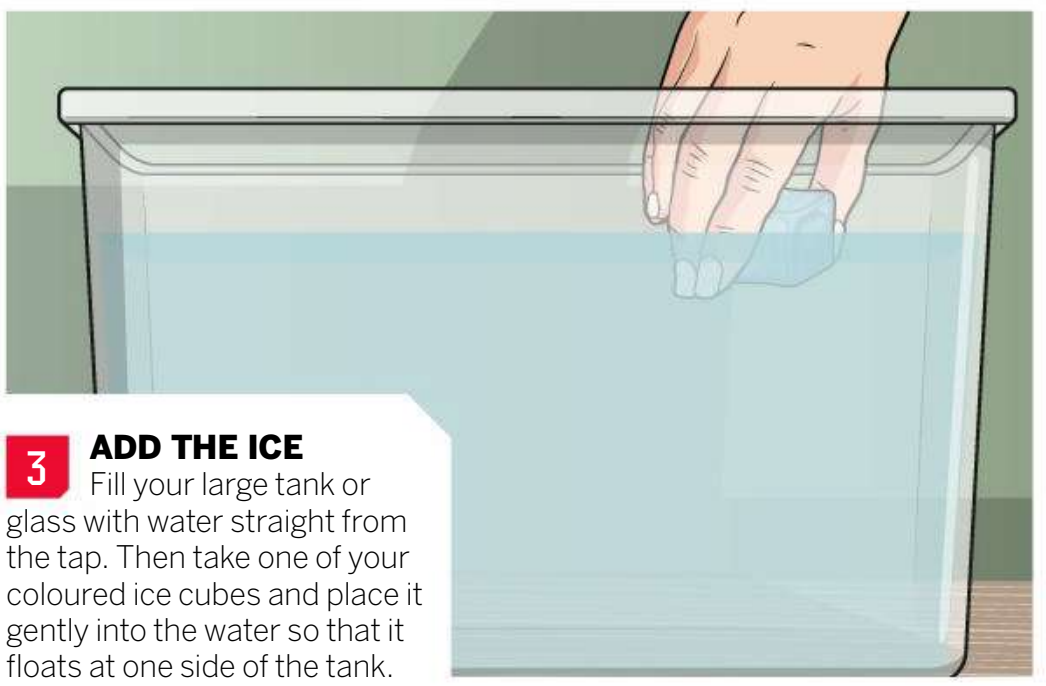
- Large see-through tank or large glass
- Water
- Two colours of food colouring
- Ice cube tray
- Narrow-necked bottle
- Tongs



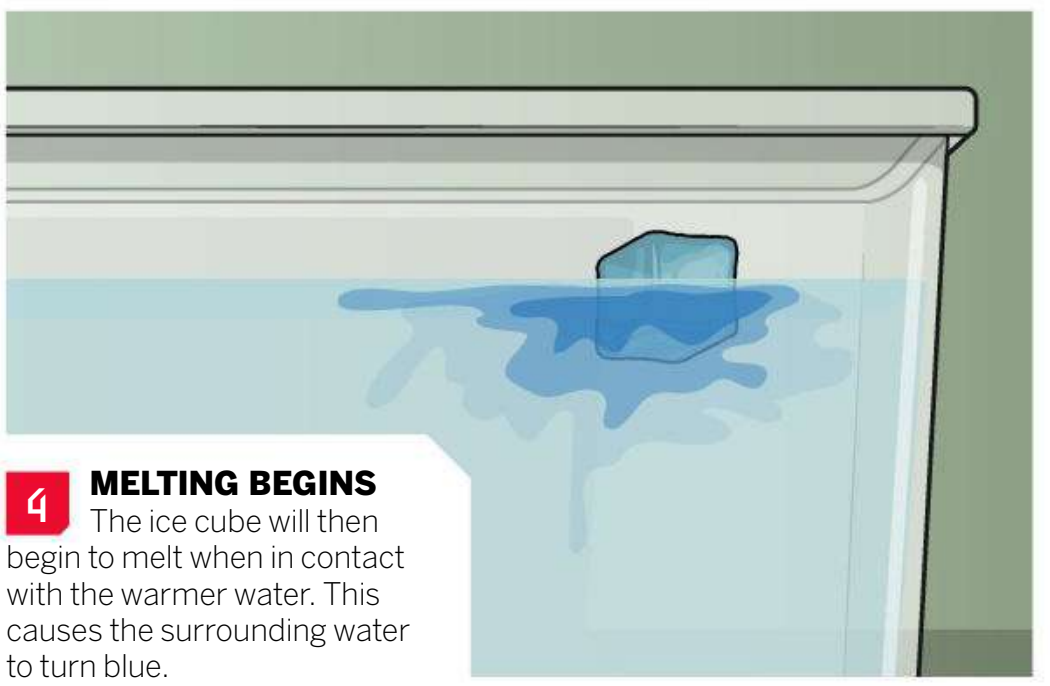
**1 COLOURFUL CUBES**
Choose a colour to represent the cold in your thunderstorm. For this example, we've chosen blue. Add water and a couple of drops of food colouring into each section of your ice cube tray and leave it to solidify in the freezer.



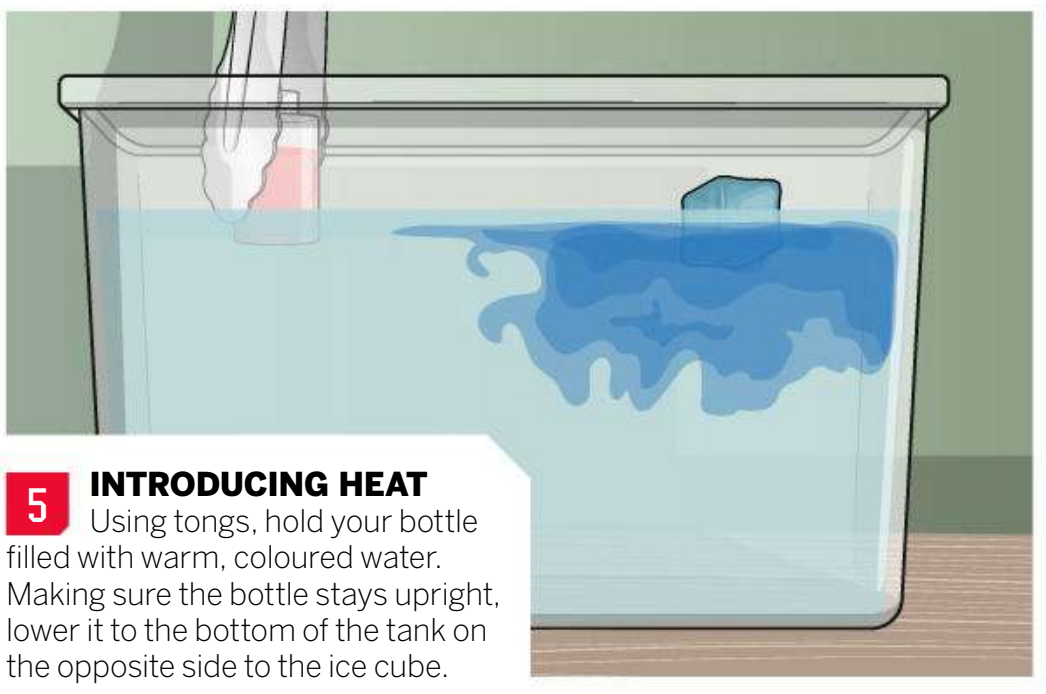
**2 CONTRASTING TEMPERATURES**
When your ice cubes are ready, prepare the warm water – not too hot! Heat enough water to fill your narrow-necked bottle. This can be done in the microwave or kettle. Add this, along with your second choice of food colouring, to the bottle.



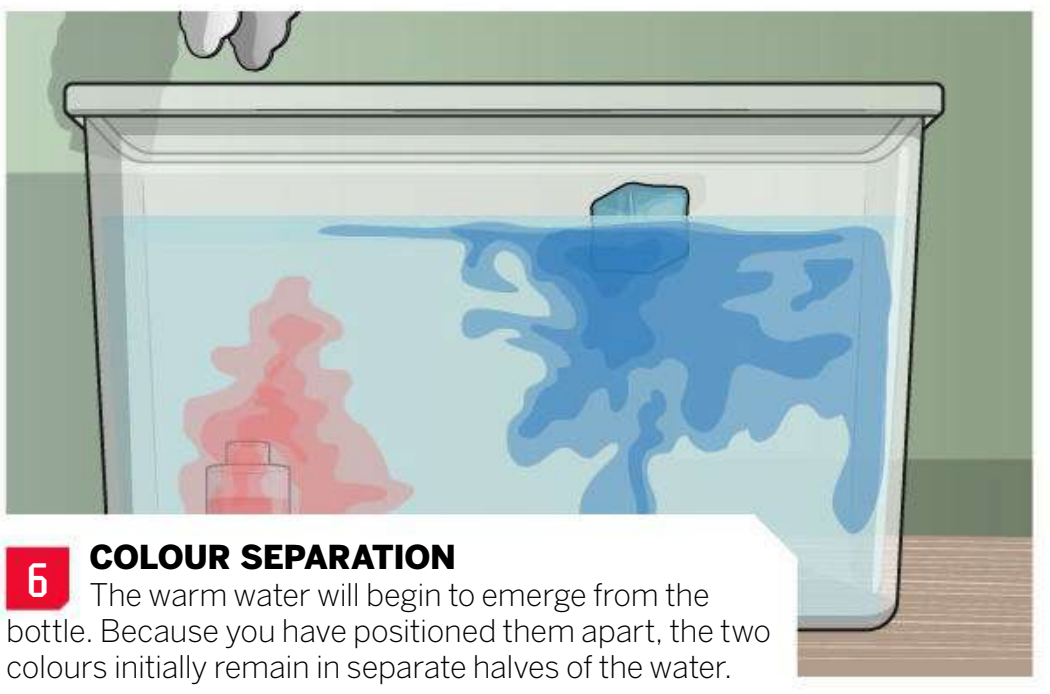
**3 ADD THE ICE**
Fill your large tank or glass with water straight from the tap. Then take one of your coloured ice cubes and place it gently into the water so that it floats at one side of the tank.



**4 MELTING BEGINS**
The ice cube will then begin to melt when in contact with the warmer water. This causes the surrounding water to turn blue.



**5 INTRODUCING HEAT**
Using tongs, hold your bottle filled with warm, coloured water. Making sure the bottle stays upright, lower it to the bottom of the tank on the opposite side to the ice cube.



**6 COLOUR SEPARATION**
The warm water will begin to emerge from the bottle. Because you have positioned them apart, the two colours initially remain in separate halves of the water.

NEXT ISSUE
HOW TO MAKE MAGIC MUD WITH POTATOES

## DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

**7 RISE AND FALL**

Which directions are the warm and cold water travelling? You should notice that while one colour rises to the top, the other falls to the base. Watch as the tank is filled with colour.

**8 CHURNING SYSTEM**

The warm water begins to cool when in contact with the cold, and vice versa. You can see the coloured water move in a cycle around the tank, and the two colours become mixed.

### SUMMARY

**When heat is transferred by a moving gas or water, this is called convection. When a lot of water is transported upwards in the atmosphere, towering clouds that make up thunderstorms can form. Warm water rises because it has a lower density than the colder, denser water. In this experiment, as the cold water sinks to the bottom of the tank, it's warmed up by the warm water and rises again.**

**When warm water vapour in the atmosphere rises, it feeds thunderstorms. Warm air near the ground rises towards clouds. The water vapour in the air then condenses to add to the cloud, releasing heat in the process. This causes convection within the clouds, with water vapour following the same pattern as this experiment. When the rising water is warmer than the surrounding air, the atmosphere becomes unstable, and can result in a thunderstorm. The cloud continues to build and expand for as long as the heat below it remains.**

## Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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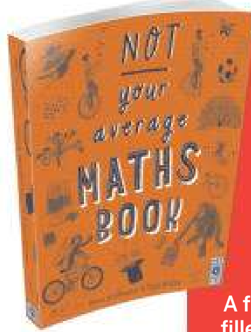


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**NOT YOUR AVERAGE MATHS BOOK**
A fun and accessible look at numbers that's filled with fascinating facts and insights into the history of numbers and the mathematicians who made key breakthroughs

## SLITHER SCIENCE

Dear **HIW**,
Why do snakes slither in a pattern? What helps them slither in the first place?
**Christopher**

**The science behind a snake's slither is intriguing. They can glide smoothly over the ground in a distinctive 'S' shape, yet despite all this winding, their direction of travel remains straight. To create this movement, the snake contracts its muscles from the neck downwards while thrusting from side to side. Snakes that live in the water and those that live on land both use this motion. For those in water, it helps them travel forwards as their bodies push against the water. Meanwhile, snakes on land are more likely to find rocks, dents in the ground and other resistance points that they can push on as they slither. To move forward, snakes rely on their ribs and the scales on their bellies. These grip the surface they are travelling across and push backwards. As they push backwards, their bodies move forwards. Most snakes glide forwards by alternating the side of their bodies that the scales are pushing from. Not all snakes slither from side to side, though. Other snakes will push backwards on both sides at the same time and travel in a straight line.**

When a snake travels in an 'S' shape, this is called serpentine locomotion

LETTER of the MONTH

## TWITTER SHOUTOUT

**@howitworksmag** Huge thanks to Mr Francis for donating a magnificent amount of **How It Works** magazines to our libraries. **HIW** is the action-packed science and technology magazine bursting with exciting information about the world around us.
**Crestwood Community School**

**Thank you to Crestwood Community School for sharing this news with us on Twitter, and thank you to Mr Francis for passing these past issues on to a worthy home. We think it's great that these copies of How It Works can be shared by so many at the school, and we hope you all enjoy them.**

These are some of the magazines donated to Crestwood Community School

## UNWANTED NOISE

Dear **HIW**,
I've been using noise-cancelling headphones at work for a while as they are amazing for concentration. However, recently I frequently hear a high-pitched noise. Can these headphones cause tinnitus?
**Gregor Reeves**

**Active noise-cancelling headphones work to cancel out external noise by producing sound waves that are out of phase with sound waves from ambient noise. While loud noise can be a cause of tinnitus, noise-cancelling headphones aren't to blame. Tinnitus is a side effect of hearing loss which causes a high-pitched ringing in the ears. If you use your headphones at a high volume, this could cause hearing loss and the resulting tinnitus. Noise cancelling itself won't cause tinnitus, but make sure not to turn them up too loud. Because noise-cancelling headphones block other noises, they can help to prevent tinnitus as they don't need to be turned up as much in noisy environments.**

These types of headphones produce 'anti-noise'

**NEXT ISSUE** ISSUE 162

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# TRAVELLING SCENT

Dear **HIW**,
When you light a candle, does the smell travel upwards?
**Jennifer Doyle**

**Yes, the smell is strongest above a candle for this very reason. The fragrance of a candle travels through rooms because air molecules are always moving and the scent diffusing. As well as its smell, a candle releases heat from the flame. The flame heats the surrounding air, and because warm air rises, it carries the scent particles upwards initially. The scent particles from the candle will soon fill the whole room, as they can move in any direction. By diffusion, the smell travels to areas with a lower concentration of these particles.**

# DENTAL DAMAGE

Dear **HIW**,
Can eating potato crisps damage your teeth? They are brittle but hard, so they can't do your teeth any good, surely?
**Stephen Conn**

**Eating potato crisps can damage teeth, but not for the reason you have suspected. Instead of damage due to the initial bite, crisps are mainly bad for our teeth because of their high starch content. The starch in crisps can get trapped between the teeth. This then turns into sugar and feeds bacteria, producing acid. After eating a whole packet of crisps, the acid produced in the mouth can last for a while and cause plaque buildup.**

# WE ASKED YOU

## This month on Instagram, we asked you: What do you think is the greatest benefit of the internet?

@YOUNGINSON
**Being able to get info you need instantly because it's so convenient and helpful**

@TIRA.__.MISU
**The greatest benefit is that a lot of lives are saved! This can change people's lives forever!**

@DUTRZ
**The greatest benefit has to be the abundance of information available at our fingertips**

@SAMMY.GLANFIELD
**Keeping in touch with the rest of the world**

@MAIA_H3
**Navigation! I would always be getting lost with paper maps! Also being able to stay in contact with friends. I've just moved countries so I love this**

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HOW IT WORKS

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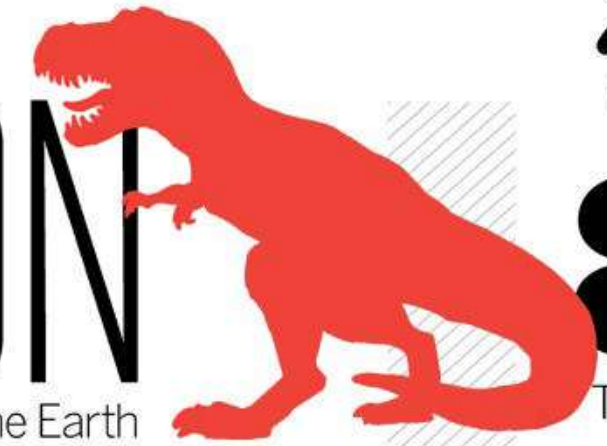
# FAST FACTS

Amazing trivia that will blow your mind

## 2.5 BILLION

The total number of *T. rexes* that ever walked the Earth



## 8,000

The total number of cars owned by Americans in 1900

## TWO MILES

A tiny stretch of water separates Russia from Alaska

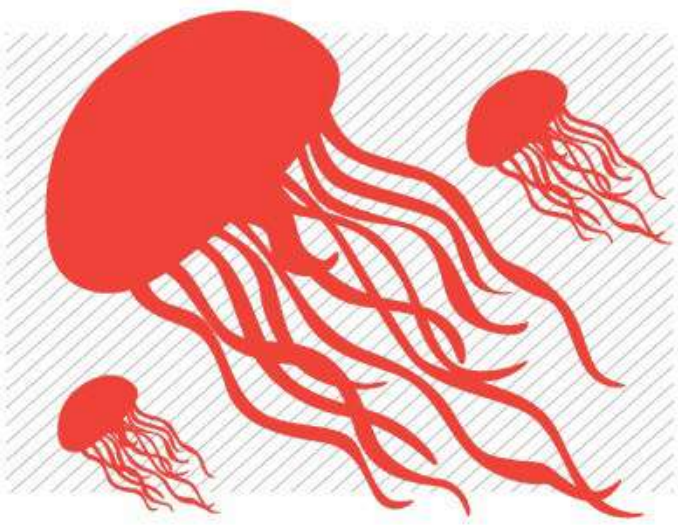
**97%**

**Most of the water on Earth is salty**

## HUMMINGBIRDS WEIGH LESS THAN A PENNY

## 7.6 CENTIMETRES

Astronauts actually grow a bit taller in space



## 16 HOURS

The world's longest flight is from Sydney, Australia, to Dallas, Texas

**Human stomach acid can completely dissolve a razor blade in two hours**

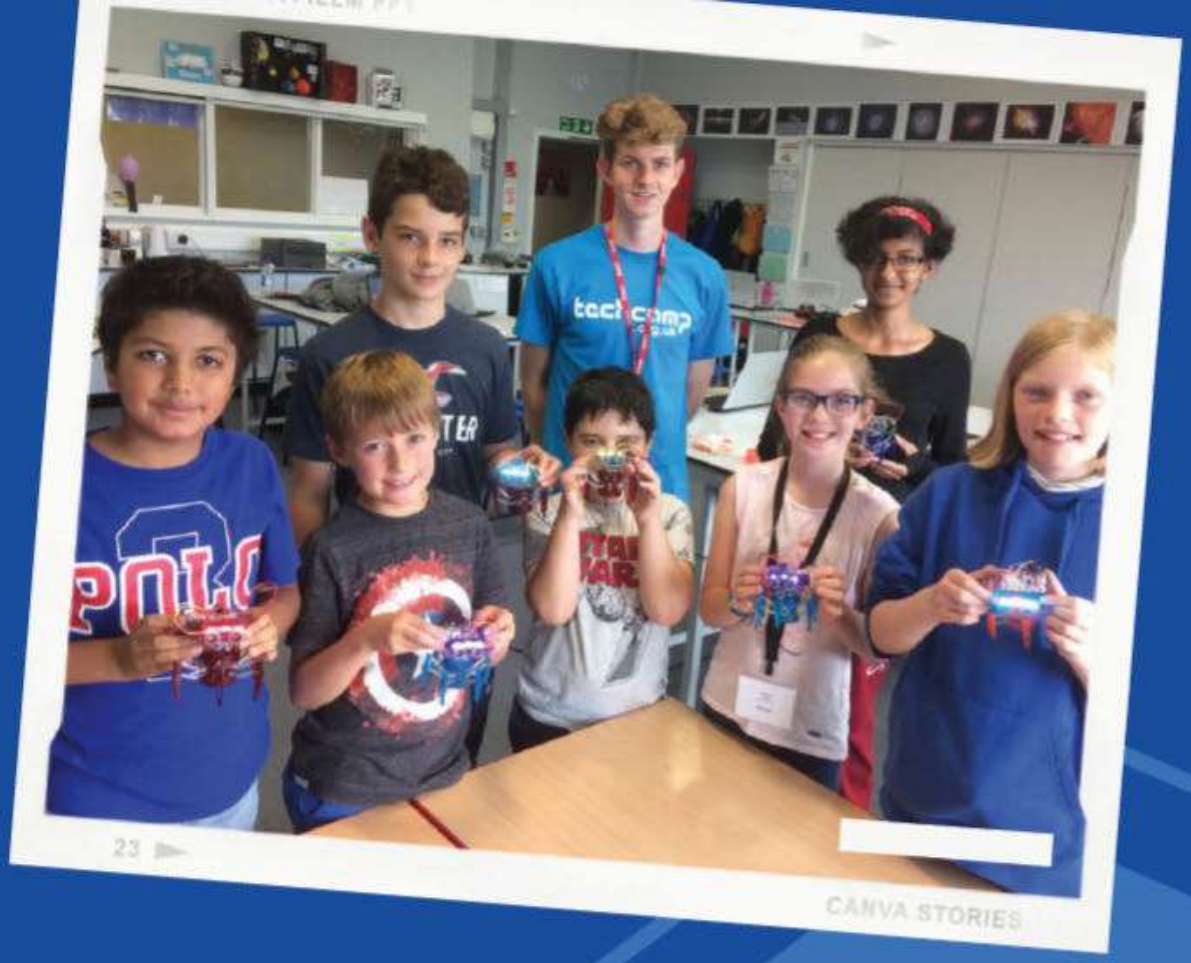
## THE IMMORTAL JELLYFISH REALLY CAN LIVE FOREVER

## 3.41 BILLION

**Beijing boasts the most annual riders of its subway system in the world**

## 1 MILLION

The number of ants per human in the world

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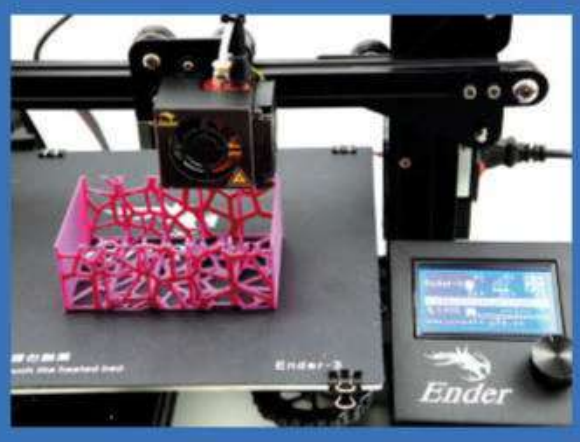


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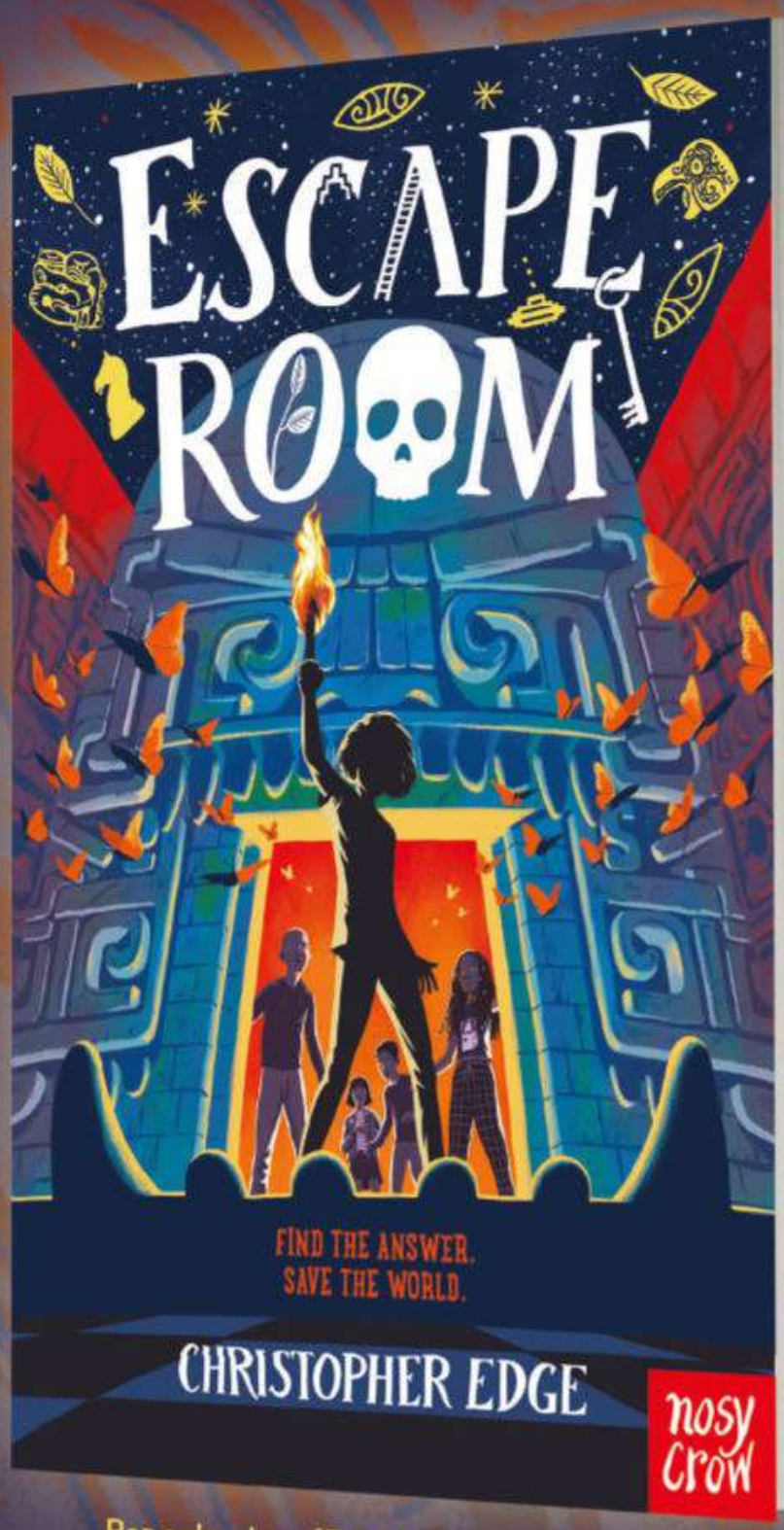


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